INTEGRATED PRODUCTION PLANNING AND CONTROL IN AN UPHOLSTERY TEXTILE FIRM

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ABSTRACT

Identification and utilization of relevant information sources for aggregate production planning in an upholstery textile firm is presented. Both the nature and content of the information sources to be used and a methodology for arriving at aggregate production decisions are developed. This effort, aggregate production planning, is related to a larger conceptual framework - that of an integrated production planning and control system. The linkages between the development of an aggregate production plan and the remainder of the system are discussed. Finally key issues related to implementation are addressed.

Interviews with company executives, visits to furniture manufacturers supplied by the textile firm under examination, and analyses of historical data are relied upon to develop and support the conclusions reached.

Historical data, market information, and other information sources are seen to enhance aggregate production planning efforts. The proposed model for arriving at such a plan facilitates the systematic and explicit consideration of the various information sources.

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CHAPTER 1.

INTRODUCTION

Among the many problems faced by companies in the industrial sector is that of maintaining efficient production operations unencumbered by material shortages. The focus of this thesis is the distribution system to facilitate production planning. The setting for our study is the Sewanee Fabric Corporation,[1] an upholstery textile firm located in Greensboro, North Carolina.

Sewanee is a major manufacturer of upholstery fabrics. Its customers include many large and well known furniture manufacturers including Kroehler, La-Z-Boy and Schnadig. In addition, Sewanee supplies fabrics to retail chains such as Sears-Roebuck and Company. Finally, it provides small quantities of fabric to so called "jobbers" engaged in selling to repair and re-upholstering shops.

Sales over the past several years have experienced rapid growth and are presently in the $45 to $50 million range. However, increasing slaes have been achieved without corresponding increases in profitability, which in fact has been particularly poor in recent years.

The relatively poor profitability sustained by Sewanee is attributable in part to the numerous problems in the production of its product. First among such problems is the diversity of the product line. Historically, Sewanee was originally a company with relatively few products. This facilitated the scheduling of weaving operations. However, with the introduction of synthetic fibers in the mid-1960's, the product line was vastly

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[1] Company name is concealed.

expanded. Raw materials and yarn types required to support the product line expansion doubled and then redoubled in number again in the short space of six years. This "explosion" of the product line resulted in many problems: inventories became increasingly difficult to monitor and control; stockout frequencies increased; scheduling of weaving operations became a manual nightmare; service provided to customers was generally conceeded to have deteriorated. Finally and perhaps most significant, Sewanee's "credibility" with its customers was tarnished severely enough that despite long-standing relationships, some customers switched to alternative sources of supply.

A second major problem facing Sewanee was its inability to gather and utilize available information, both internally and externally, in the planning and control of its production operation. The precise nature of such information will be elaborated on in subsequent chapters, but suffice it to say there existed no systematic effort to collect, analyze, and utilize available information.

The purpose of this thesis will be to develop a strategy for collection of information so that it may be profitably used to support management decisions in the area of production planning. The structure we proposed is embedded in a larger framework of integrated production planning and control which will be presented in subsequent sections.

In developing our model we first examined material and information flows as they presently exist. Concurrently we undertook analyses of Sewanee's product market and the upholstery textile industry in general. We performed detailed analyses of historical sales data to discover product line performances, customer characteristics, product mixes, and other

relevant information. We were subsequently able to meet with several of Sewanee's customers to ascertain what sources of information were available from them that might prove useful to Sewanee, and in turn what Sewanee might do to improve its service to such customers. We next developed a normative framework (model) describing our perception of how identifiable sources of information might be included in a formalized aggregate production planning routine and how these decisions link to the larger framework. Finally we addressed specific implementation issues. Before proceeding, however, a brief introduction to Sewanee is appropriate.

Sewanee's operation may be described as a four-stage process as diagramed in Figure 1. Raw materials are obtained and spun into yarns. Yarns are placed on "cones," "spools" and "beams" which are used on looms to weave the fabrics. Finally the finished product is shipped to customers. This

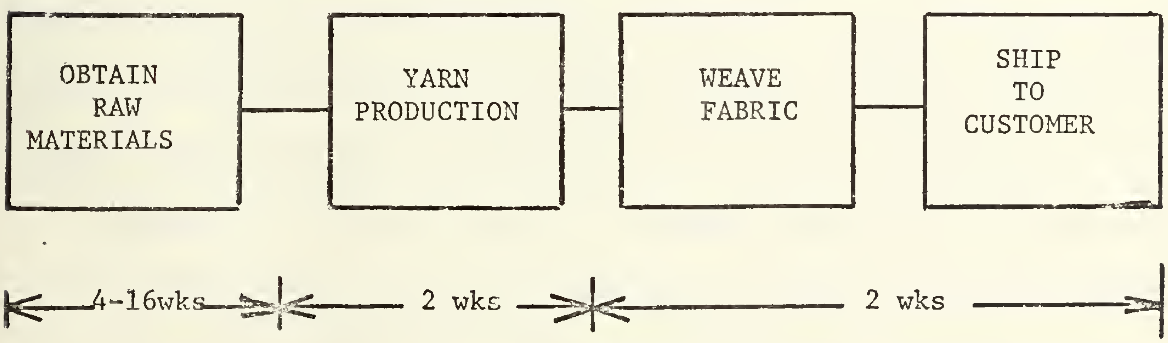

FIGURE 1. FOUR STAGES OF OPERATION AT SEWANEE.

description is clearly quite simplified. However, the time lags involved in the process are quite important, and as illustrated in Figure 1 they can be lengthy relative to the weaving operation. The product cycle, from spinning of yarns through shipment is approximately four weeks, under normal loads. Lead times for obtaining raw materials will vary, but four to six weeks is not uncommon and much longer times (up to 16 weeks) are often experienced for certain classes of raw materials. Sewanee's customers are anxious to obtain realistic delivery dates from the mill. Their production processes and their ability to meet the demand of the furniture market depend heavily on timely receipt of fabrics from their suppliers. With a total lead time of eight to ten weeks it is incumbent upon Sewanee to be continually aware of where it stands regarding raw material availability and on-hand inventories of yarn.

A critical success factor, then, is to insure that internal operations are sufficiently coordinated and linked so as to reduce the possibility of material shortages and production inefficiencies. The mill would like to quote its customers delivery dates and lead times with full assurances that it can schedule its weaving operations to meet such commitments. Clearly the attainment of this goal requires thorough planning and coordination.

The methodology presented in this paper attempts to group the various activities of the textile firm in a manner that will facilitate coordination and control. Figure 2 illustrates the major components of the model we propose.

Aggregate production planning is at the heart of the system. Through this function the coordination and integration necessary for the proper functioning of the system as a whole are conducted, including the master

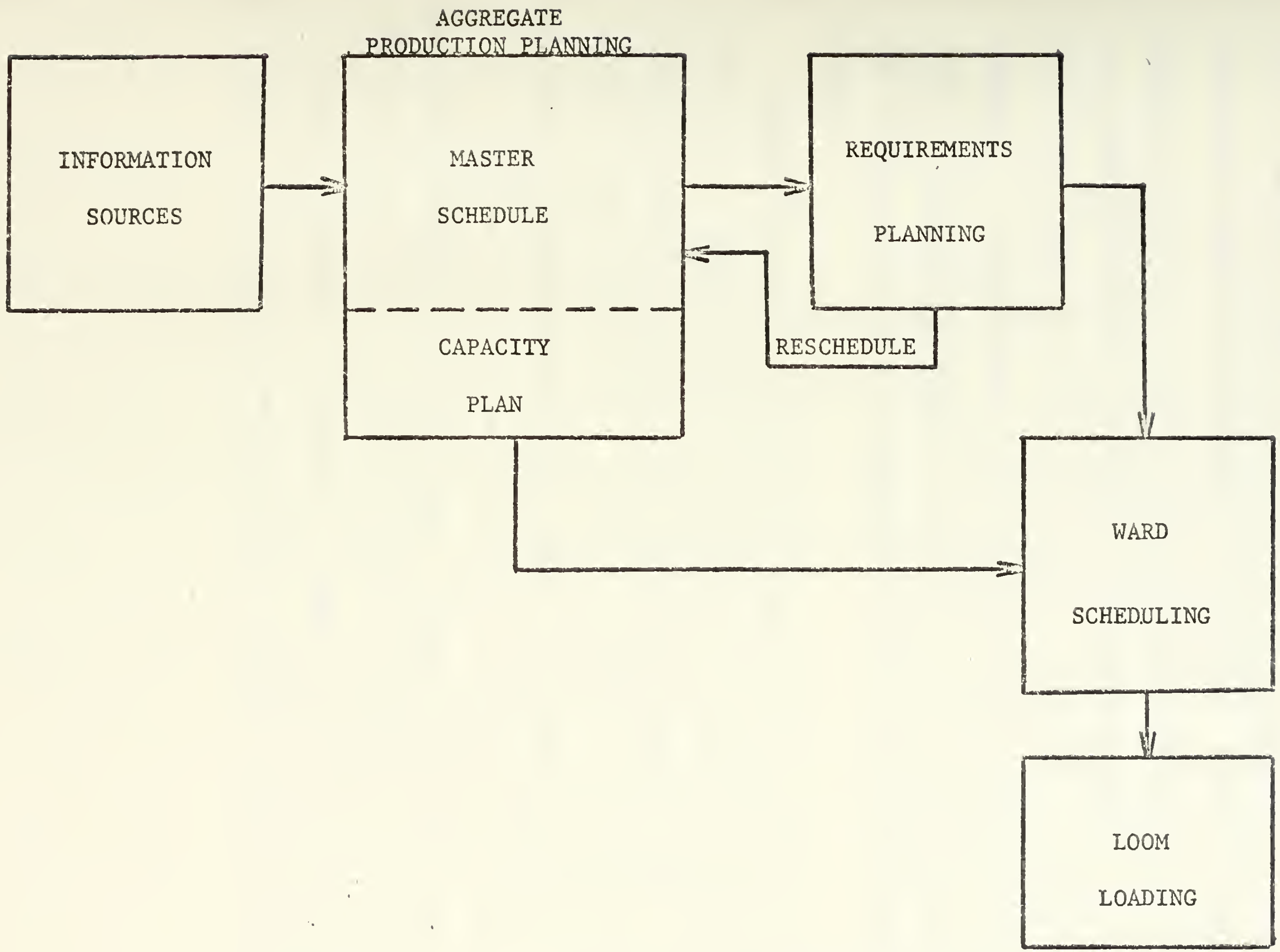

FIGURE 2. MAJOR COMPONENTS OF AN INTEGRATED PRODUCTION PLANNING AND CONTROL FRAMEWORK.

schedule and the capacity plan. The master schedule delineates what the mill is planning to produce during the planning horizon. The capacity plan reflects the productive requirements of the master schedule. Requirements planning is performed through a bill of materials explosion routine, based on the planned production specified in the master schedule. If the master schedule has taxed too heavily the capacity of the mill to produce the yarn components, a rescheduling process is called upon to change the master schedule. Detailed scheduling, which includes both warp scheduling and loom loading, follows from the aggregate production and requirements planning processes.

Clearly we have but scratched the surface of the problem in this brief introduction. However, with the perspective so obtained we proceed to focus our attention on the critical production planning process. The remainder of this thesis will be devoted to expanding our knowledge of this area and to designing an applicable model of the tasks necessary to carry it out. Chapter 2 will review the conceptual framework of an integrated production planning and control system. Chapter 3 will review the characteristics of the upholstery industry and Sewanee in particular. Chapter 4 will present and describe in detail our model. In Chapter 5 we address implementation issues and then conclude with the final chapter.

CHAPTER 2.

INTEGRATED PRODUCTION PLANNING AND CONTROL

Application of integrated planning and control techniques has been an implicit objective of many manufacturing firms since their inception. Essentially what is meant by integrated production planning and control is the explicit and formal linkage of the major components in the firm's operations. More specifically, the process of producing the product from planning based on market information to the distribution of the final product must be included in the definition of integrated production planning and control. It is the purpose of this chapter to explore the basic objectives of integrated production planning and control systems, production environments in which they are most beneficial, available information on integrated planning and control in the literature, and finally, criteria by which integrated production planning and control systems may be evaluated.

2.1 Why Integrated Production Planning and Control?

The most natural and potentially most useful application of integrated production planning and control systems occurs when a manufacturer has a multistage production process that requires precise timing in the delivery of components to assembly phases. It is under these conditions that integrated production planning and control systems are capable of reducing inventory costs, both work in process and finished goods, while allowing better scheduling of human and material resources, and maintenance of good response to demand fluctuation.[1]

[1]William K. Holstein, "Production Planning and Control Integrated." Harvard Business Review. May-June 1968. P. 73.

The production function in the firm is obligated, as are the other functional elements of the firm, to plan, budget and justify requests for the firm's resources.[2] To better prepare for the planning process, production management obviously needs good information, not all of which will be internally generated by the production department. Moreover, failure to coordinate marketing and field information with the capacity planning and budgeting process can have devastating effects on the firm's ability to get the product out the door in the proper model mix and distribution pattern. Clearly, the effective use of available information in the manner suggested above tends to force more realistic consideration by production management of its role in the firm's operation. The added benefit of explicit linkage of other information sources is thus an issue to be discussed in the following text.

At the outset, the firm must analyze future market requirements. Not only must factors such as product demand and market character be noted, but the need exists for substantial insight into changes in market requirements. A second important feature of integrated planning and control systems is the priority given to the firm's analysis of its capacity limitations, both human and material. An intimate knowledge of capacity is a prerequisite to a successful planning system. Lastly, it might be pointed out that on the basis of the information analysis of market requirements and capacity, an integrated planning and control system allows the firm to make longer-term capacity planning decisions for plant, equipment, work force, and inventory commitment by providing a structure whereby the relevant information for these decisions can be collected and examined in the context of the firm as a whole.

[2]Ibid. P. 75.

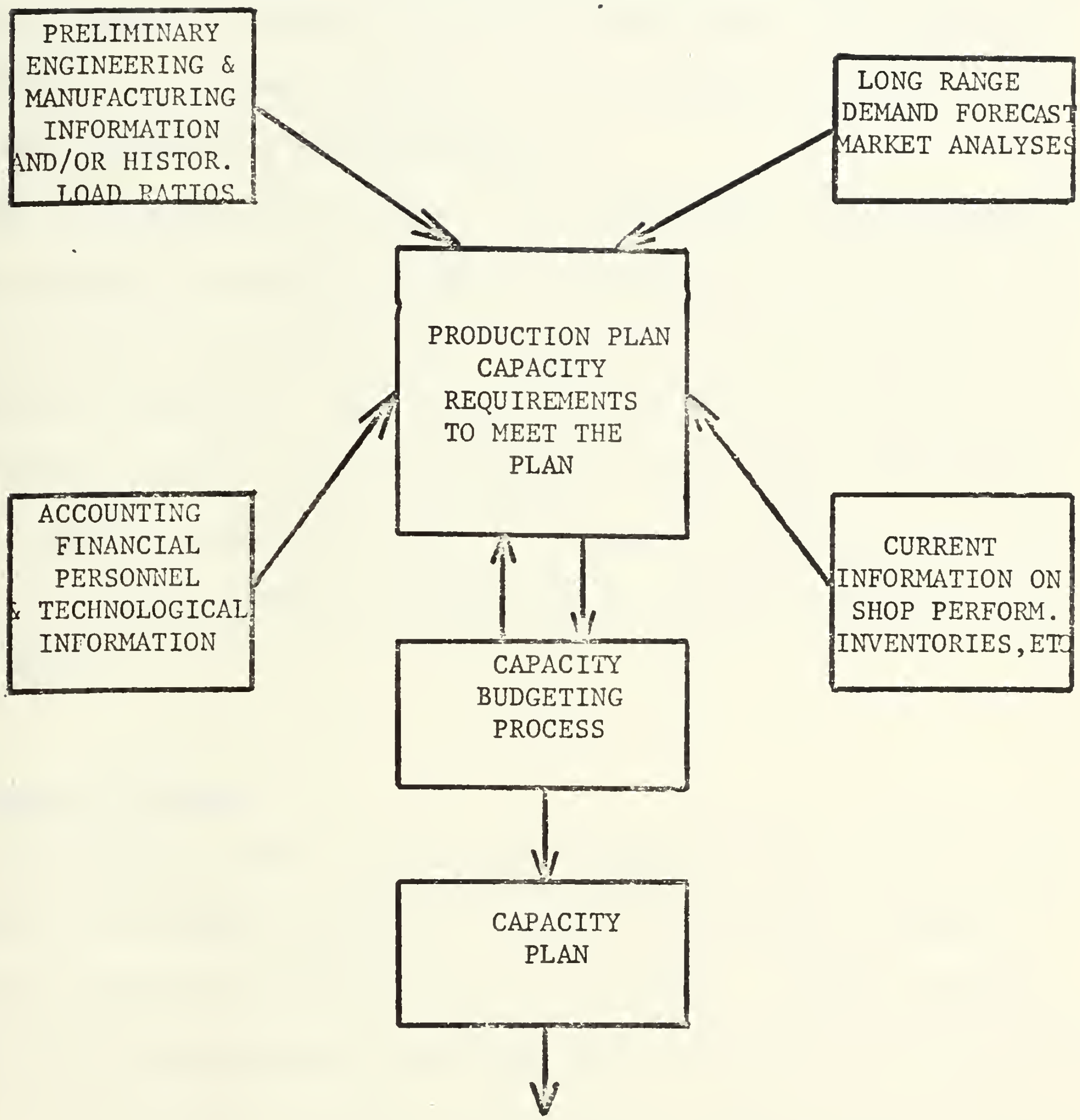

FIGURE 3. CONCEPTUAL CAPACITY PLANNING PROCESS.

Looking at a shorter time horizon, the time of the production cycle, the integrated production planning and control system must meet the challenge associated with the problem of effectively and efficiently allocating productive resources within a much shorter time frame. Essentially the scheduling of day-to-day requirements at the work center level quite naturally proceeds from the aggregate plan.

The following sections dissect a normative model of an integrated production planning process and attempt to demonstrate how information and material flows can be coordinated. Specifically, issues surrounding the information required for capacity planning, the master scheduling process, and detailed scheduling will be discussed and the linkage between these phases stressed. The final section will discuss criteria for the evaluation of integrated production and planning and control and summarize the major issues.

2.2 Capacity Planning

The literature offers only limited insight into the specifics of the information requirements generally considered for capacity planning in integrated production planning and control systems. A rather complete approach has been presented by Holstein[3] and will serve as a guide for the major issues presented. Figure 3 diagramatically presents the conceptual capacity planning process.

Key to the success of capacity planning activities is the forecast (both long-range and short-range) of demand. In an integrated production planning and control system, the linkage is such that grossly inadequate preparation of the demand forecast translates into serious problems in

[3]Ibid. P. 73-92.

downstream activities. Depending upon the type of firm, this high degree of coupling may be more or less successful. Clearly in a firm requiring rapid response to demand for a product utilizing multi-stage production capabilities, the highly coupled system provides a potentially valuable alternative.

The type of forecast used in an actual application may vary along the spectrum from very quantitative to very subjective management input, or combinations along the spectrum.[4] Extrinsic forecasting is generally required to gain a broader perspective and more responsive behavior as demand fluctuates with external factors. Simply stated, the relationship between demand and such factors as aggregate economic indices plays a critical role in the firm's ability to plan for shifts in market demand.

Extrinsic forecasting generally requires considerable amounts of historic data, analytical analysis of the data, projection of the results of historical analysis into the future, and finally, revision of the model with the availability of new demand data.[5]

The objective of forecasting is to allow management to plan for future events in order that they might more nearly meet customer demands while minimizing the investment necessary to achieve this service. Typical areas where accurate forecasting can be helpful include control of inventory levels, labor force, and physical capacity.

In addition to the need for a forecast of expected product performance, more subjective input can be offered by management to modify demand expectations if market irregularities are anticipated. It is crucial to the

[4]"Communications Oriented Production Information and Control System." IBM Publication No. GE 20-0280.

[5]Ibid. P. 52-56.

success of a forecasting operation for the individuals involved to maintain survelliance on market conditions to assure the continuing validity of any forecasting model.

In addition to a forecast of expected product requirements, information from engineering and product development groups concerning product modifications, competition, or new introductions is quite valuable in determining what capacity will be needed to meet future requirements.[6] Additionally, in closely coupled industries information regarding downstream demand, inventory policies, etc., is often quite helpful.

Production planning is the next stage in the process. The transformation of forecasted product demand coupled with information on current production performance, inventory, personnel, etc., into an aggregate production plan and the requirements to support the plan is the first step in integrating the collected information. Based on the aggregate production plan, the capital budgeting process is initiated. Longer term decisions as to capital expenditures can be based on the expected level of activity. Supporting financial, technical, and personnel information aide this process directly.

The ultimate objective of the above procedure is a capacity plan depicting the work force level, expected capital investments, aggregate inventory levels, and planned production schedule. The formation of this plan is central to the issue of allocating the productive resources in the most economic manner to achieve desired results. In the following section master scheduling will be discussed and the critical link between capacity

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[6] William K. Holstein. "Production Planning and Control Integrated." Harvard Business Review. May-June 1968. P. 76.

planning and master scheduling, i.e. the constraint which the capacity plan imposes on master scheduling, will be discussed.

2.3 Master Scheduling

The master scheduling process again presents a situation where multiple sources of information are integrated into a planned activity schedule. The ultimate objective of the master schedule is a rough time schedule for production of the final product. In the following paragraphs and in Figure 4 the outline for moving from the basic information sources to the master schedule will be explored.[7]

As is the case with the long range capacity planning process, a basic input to the master scheduling process is a forecast of expected sales. The nature of the sales forecast at this level is generally more detailed than the extrinsic forecast proposed for long-term planning. Typically, the aggregate sales forecast would be the composite sum of intrinsic forecast for individual products. Notably, the reliance is primarily on historical data at this level in the planning system. The requirement for intrinsic rather than extrinsic forecasting arises from the need for more detailed information on individual products as a direct input into the short-term scheduling process. Typically,multi-product companies would be unable to use extrinsic forecasting for this purpose because of their inability to disaggregate a sales forecast into separate product forecasts and still maintain significant accuracy.

In addition to forecasted and actual customer orders, stock status and inventory information from all levels within the firm are assimilated with

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[7] Ibid. P. 77-79.

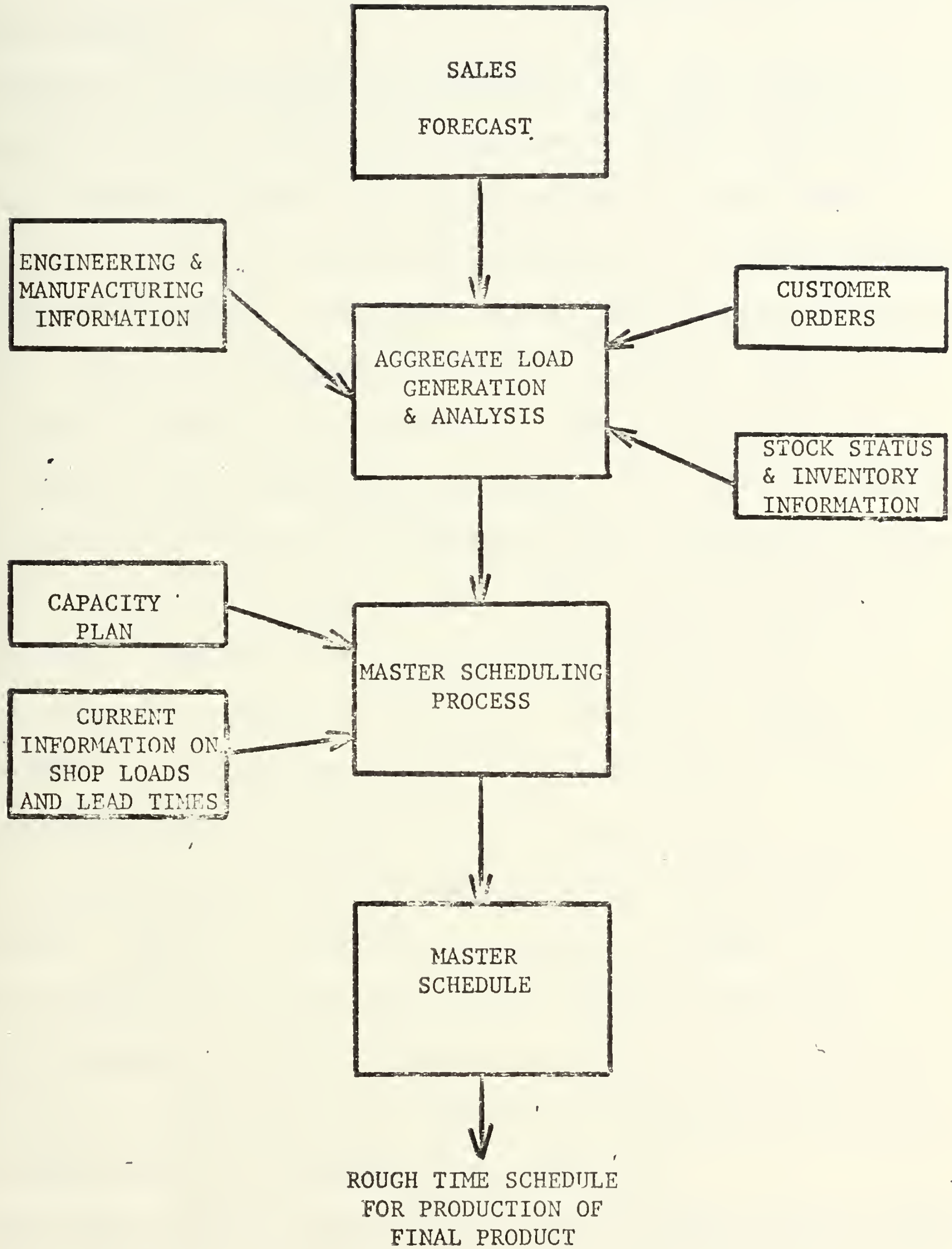

FIGURE 4. MASTER SCHEDULING PROCESS.

available manufacturing information to produce an aggregate load for the production facility.

Following the preparation of the aggregate load, the capacity plan and information on current performance levels serve to define constraints for the master scheduling process. The actual process of master scheduling involves the allocation of production requirements over the planning horizon in a time-phased sequence. Two methods are available for accomplishing this objective. First, the facility may be loaded to capacity. That is, capacity both in terms of human and material resources is explicitly defined, component parts requirements are exploded from a bill of materials, and the due date for each part is determined by back dating from the master schedule's due date for the final product. Work centers are then loaded by the assignment of specific jobs until the stated capacity is met. For those jobs that cannot be scheduled, either the due date must be changed, capacity must be added, or alternatives such as subcontracting must be evaluated. A second loading scheme is referred to as "infinite capacity" loading. Using the same approach as capacity loading, load is accumulated at each work center. However, no consideration is given to overloads. This approach points out bottlenecks and problem areas that management may adjust by a variety of decisions. Trade offs between the two approaches emphasize the variability in manufacturing cycle time, and hence delivery performance, versus equalization of the production load over time.[8]

The resulting master schedule depicts the time-phased expected requirements on the production department. It should be emphasized that this is a rough approximation prepared in an attempt to realize potential problem areas and to assure that the production function's resources are used in an economic manner.

[8]Ibid. P. 81-83.

The master schedule provides the link between the aggregate planning process and the detailed scheduling phase. The time-phased representation of the production plan provides the outline within which individual orders can be scheduled to particular work centers. The following paragraphs will briefly discuss this process.

2.4 Detailed Scheduling

Immediate distinction between detailed scheduling and master scheduling can be drawn along two lines. First, the time horizon differs for the two processes. Short-term scheduling effects the day-to-day or weekly assignment of work loads at specific work centers. Master scheduling, on the other hand, produces a longer term, perhaps two to three month look at the aggregate capacity requirements. Secondly, detailed scheduling is concerned with the preparation of a schedule for individual customer orders. This association of a specific order with the schedule is not generally made in the master scheduling phase.

Figure 5 diagrams a conceptual detailed scheduling procedure. Although many of the input parameters appear to be identical with those used in the master scheduling process,the detail and amount of information to be processed is generally much greater.

The flow of information from the master schedule to the final short-term schedule is worth discussing at some length. The initial step involves the explosion of the time phased requirements into individual components. Following the explosion, parts requirements are netted against available inventories. The sequence then schedules orders subject to constraints imposed by the capacity plan and current machine loads, lead times on

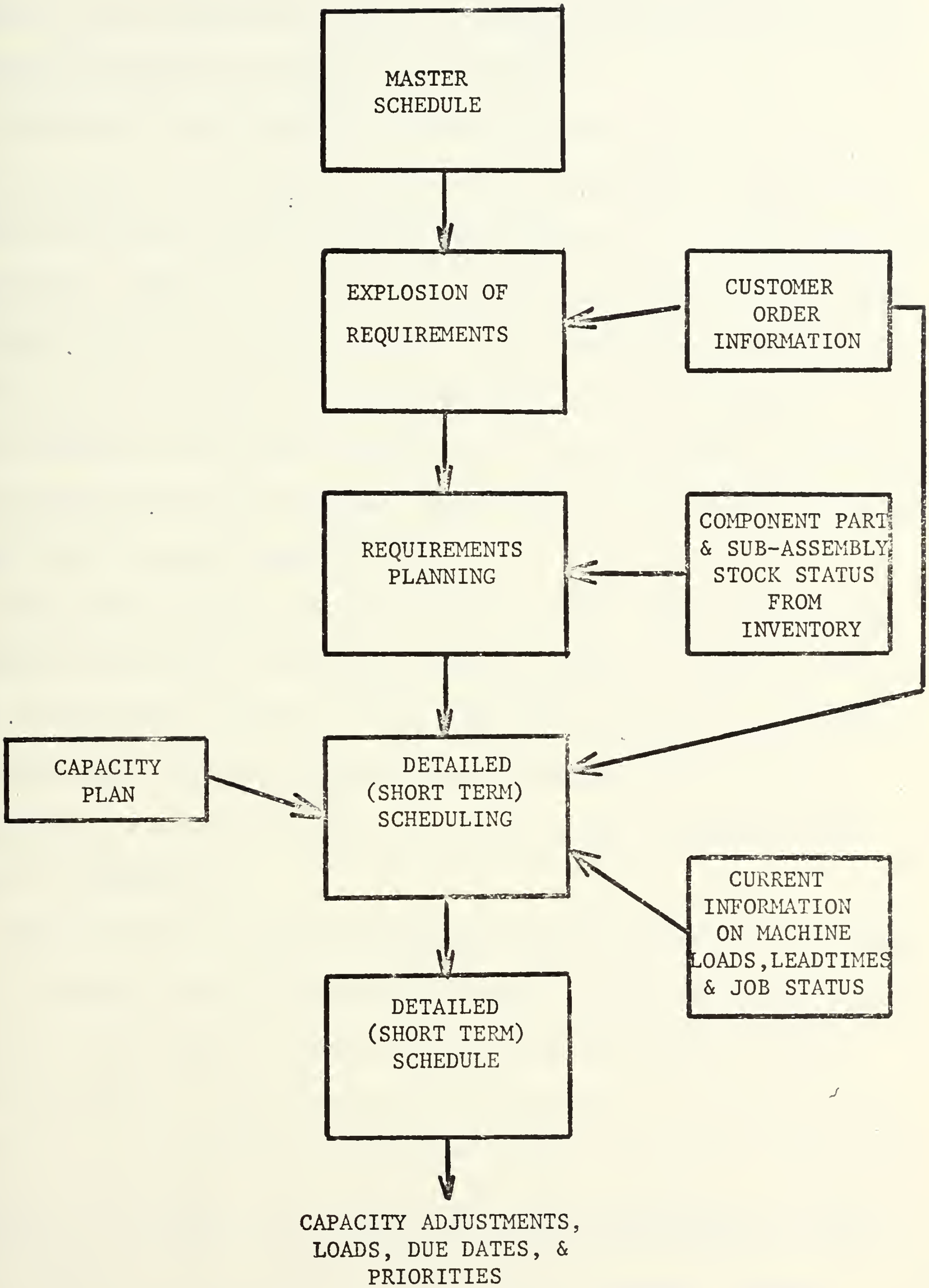

FIGURE 5. DETAILED SCHEDULING PROCESS.

components, and job status. The resulting short-term schedule provides a guide for the allocation of loads to specific work centers and details the timing planned for the production activity.

There are a wide variety of dispatching rules currently used for short-term scheduling. The tradeoffs between cost performance, manufacturing cycle time, and due date performance make evaluation on an individual case a necessity. Some of the more common procedures used include "earliest due date," "first come, first served," and "shortest processing time." Each method has a specific objective and must be used accordingly. It is also worthwhile to note that combinations of these and other methods have been applied with varying success. The "critical ratio" method and "minimum slack" rules are common examples.[9,10]

The priority dispatching scheme used for short-term scheduling can vary from very simple to extremely complex in terms of the amount and currency of information required. When evaluating systems with dynamic dispatching rules it is quite important that the information processing requirements be carefully evaluated in terms of both availability and quality of information.

The payoff from a properly designed dispatching system can be quite high. Specific areas where improvement might be expected include reductions in the amount of clerical work required to maintain current records, reduction of work in process inventories, and increased availability of useable information regarding capacity control.[11] Elaborating

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[9] Buffa, E.S. and Taubert, W.H. Production Inventory Systems: Planning and Control, Homewood: Richard D. Irwin, Inc., 1972, pp 495-6.

[10] G. W. Plossl and O. W. Wight. Production and Inventory Control: Principles and Techniques. 1967. P. 296-300.

[11] William K. Holstein. "Production Planning and Control Integrated." Harvard Business Review. May-June, 1968. P. 88-89.

on this last point, the improved information should allow the shop floor supervisor to better adjust machine loadings if bottlenecks occur. This allows readjustment for the inaccuracies that would naturally be expected from the aggregate scheduling process.

2.5 The Integrated Planning and Control System

It is not uncommon to find individual firms that do quite well in the implementation of the separate components of integrated production planning and control systems; but few have been able to tie the parts together to form a balanced planning system. This is to say that isolated elements of integrated production and control systems can be found, but examples of effective linkage of the elements is rare. The information processing requirements, the lack of sufficient or useful data, and the fact that the processes that are critical links,such as lead times or components,are probablistic rather than deterministic increase the difficulties encountered in developing a completely integrated system by several orders of magnitude.

The framework that has been presented is intended to provide a basis for management decisions at all levels in the production process. Rather than a statistical EOQ-recorder point inventory control system, the entire production process is included and linked along lines of commonality of information flow.

Lastly, it is desirable to specify criteria by which the production planning and control system's performance can be evaluated. The most common measures cited include inventory investment, labor costs, manufacturing cycle time, equipment utilization and due date performance.

The flexibility offered by the integrated approach to production planning and control greatly enhances management's ability to plan both at the aggregate capacity level and the detailed scheduling level-all within the same framework. Perhaps an even more valuable contribution is the assistance provided in structuring available marketing and internal information flows in a form that is compatible and directly linked to the actual production planning process. No longer is production a separate entity operating in a vacuum with respect to the other functional elements of the firm.

CHAPTER 3.

CHARACTERIZATION OF THE FIRM

3.1 Introduction

This chapter is intended to provide a characterization of the product market segment within which Sewanee operates and serves its customers, and an analysis of the current material and information flows at Sewanee. To accomplish this characterization the following sections will discuss the environment within which Sewanee operates, the nature of the customer market served, and the historical sales performance of the firm. An added benefit of this approach is the fact that many of the input parameters of the integrated planning and control system will surface during the process of examining the current situation.

3.2 The Upholstery Industry

The upholstery manufacturing industry is made up in general of many small firms, most of which specialize in a particular type of fabric. A few of the larger firms such as Chatham Mills and Sewanee offer broader lines with many style/color combinations in each major area.

Sewanee's $47 million sales level in 1972 makes it the largest entrant in the industry. Needless to say, in an industry heavily influenced by stylistic considerations Sewanee's growth to its present size has taxed the ability of its manufacturing function to meet the demands placed on it by the marketing function. Recent trends in the furniture industry have added to this problem. Most notably, the concept of retail showroom warehouse marketing of furniture has created new pipe lines which must be filled.

In addition, the growing affluence of consumers has contributed heavily to increased demand for upholstered furniture.

Because the furniture manufacturers that comprise the major market for Sewanee's products are generally small businesses, they are unable to maintain large inventories of upholstery materials. Hence, we would expect Sewanee's demand to vary closely with that of the furniture industry. Key economic variables to be considered in the evaluation of expected levels of future demand should therefore include personal disposable income, number of family formations, new housing starts, population growth, credit availability, and consumer buying sentiments. In the past year the sizeable reduction in wood availability and surge in prices of wood has made upholstered furniture an attractive economic alternative to finished wood products.

The industry places a number of marketing demands on Sewanee that are critical to the understanding of the product life cycle and level of demand for new products. Major furniture shows are held four times annually in the United States. It is at these shows that Sewanee's new fabrics are introduced on the furniture manufacturer's product. Major shows are held in April and October in High Point, North Carolina, and in January and June in Chicago, Illinois. Large order placements for furniture covered by Sewanee fabrics take place at this time.

Other orders for Sewanee fabrics are generated through contact by salesmen with the furniture manufacturers and the jobbers who buy fabrics for resale. Sewanee's sales force is divided into five regional sales offices and an international division, each having a regional manager and from one to four salesmen. The domestic sales regions are located in New York, North

Carolina, Chicago, Dallas and Los Angeles. International offices are maintained in New Zealand, Australia, Dusseldorf, and Rotterdam. The primary function of the sales force is to carry the product in sample form to the customer and to collect orders.

The outlook for Sewanee's markets appears relatively unchanged from past performance levels. The primary problems involve raw materials requirements planning and increased ability to meet market demand with reasonable lead times on finished products. The existence of many small firms supplying specialized needs makes market response time an important variable if Sewanee is to retain its large market share.

Another important consideration in the industry is the problem of price competition. Several of the smaller upholstery firms commonly practice a "follow the leader" strategy for new product introductions. That is, they are shown swatches of new fabric introductions by a furniture company and are asked to make a cheaper copy. Or they visit furniture shows, copy fabrics and introduce them at reduced costs. In an environment characterized by such price competiveness, a strong marketing emphasis can be expected when evaluating the firm's activities, especially product market decisions.

The preceeding discussion has developed a number of considerations related to the environment within which Sewanee operates. A better understanding can perhaps be gained by examining more closely analyses of the Sewanee's product line and customer characteristics respectively.

3.3 Analysis of the Sewanee Product Line

The product line at Sewanee has seen many changes in recent years. Most notably there has been a significant increase in the number of styles

TABLE 1. SEWANEE SALES VOLUME BY MAJOR PRODUCT LINES.

	YEAR	1970	YEAR	1971	9 MOS.	1972	9 MOS.	1973
FABRIC	$ (000's)	%	$ (000's)	%	$ (000's	%	$ (000's)	%
POLY	18,318	62.4	21,904	69.2	21,741	69.5	20,680	66.1
FLATS	6,914	23.6	3,174	10.0	1,442	4.7	1,267	4.1
CRUSHED VELVETS	2,067	7.0	4,423	14.0	5,519	17.5	4,574	14.6
PILE	1,356	4.6	1,125	3.6	697	2.2	822	2.6
TUFTED	-	0.0	74	0.2	615	2.0	543	1.8
DOMESTIC VELVETS	709	2.4	641	2.0	193	0.6	92	0.3
PRINTS	-	0.0	341	1.0	1,087	3.5	3,298	10.5
TOTALS	29,364	100.0	31,682	100.0	31,294	100.0	31,276	100.0

and colors offered. Additionally, with the advent of synthetic fibers, the number of major product lines has increased.

The present product line includes seven major product types. These are: crushed velvets, prints, tufted fabrics, poly's,domestic velvets, flat and pile fabrics. Table 1 presents a breakdown of the sales volume attributable to each of these major lines. It is significant to note that the largest segement of Sewanee's business is in the poly line. The implications of this point will be clearer when the analysis of historical data is discussed.

The current product line expanded from 5,281 styles and colors in 1972 to 5,330 in 1973. It has been previously felt by Sewanee management that the marketing requirements of their industry dictate a broad product line as a prerequisite for growth. The impetus has therefore been for a continual introduction of new product styles with a large number of color offerings. It is not unusual for a basic style to be introduced in 25 different colors. The proliferation of this large number of styles and colors can be attributed to Sewanee's attempts to gain market share in the late 1960's. Ample attention is given to the stylistic considerations of new product introductions but little economic planning is done.

To better understand the product line at Sewanee, consideration of the basic fabric components is appropriate. The two major items are the warp and the fill yarns. The production process involves the weaving of a number of fill yarns with a warp to produce the pattern. The expansion in the number of styles has been accompanied by large increases in both the fill yarns and warps required for the product line. Table 2 exhibits the statistics for 1972 and 1973 warp and yarn useage.

TABLE 2. WARP AND YARN USAGE SUMMARY.

	AUG. 1969	MARCH 1970	JAN. 1971	JAN. 1972	JAN. 1973
YARNS	572	790	843	1287	1758
WARPS	*	*	*	112	284
STYLES/COLORS	*	*	*	5281	5330

*not available

TABLE 3. CUSTOMER SALES VOLUME ANALYSIS, 1972.

	CUMMULATIVE # OF ACCOUNTS	CUMMULATIVE % OF TOTAL ACCOUNTS	CUMMULATIVE SALES (000's)	CUMMULATIVE % OF SALES
ACCOUNTS OVER $300,000	25	3	$24,131	63
ACCOUNTS OVER $200,000	35	4	$26,549	69
ACCOUNTS OVER $100,000	61	8	$30,173	78
ACCOUNTS OVER $50,000	97	12	$32,739	85
ALL ACCOUNTS	794	100	$38,422	100

The large increase in the product line requirements has greatly increased both scheduling and planning problems at Sewanee.

3.4 Customer Analysis

As noted earlier, the customer market served by Sewanee is characterized by many small firms manufacturing a large variety of furniture styles. Analysis of Sewanee's sales data by customer account indicates, however, that a large percentage of the firm's sales are attributable to a relatively small number of customers. Table 3 gives a breakdown of the actual statistics for 1972.[12] It is significant to note that 12% of Sewanee's customers account for 85% of total sales dollars.

The nature of Sewanee's customer buying patterns is of further interest in the characterization process. With its broad product line standing as the source of many scheduling problems, which result in excessive set up costs and labor costs, Sewanee is quite naturally searching for ways to reduce its product line offering and subsequently the associated scheduling problems. To demonstrate to Sewanee's management that selective deletions in the product line could be accomplished without adversely affecting sales volume, a simple analysis of 1973 sales data was constructed as described below. There were two objectives of this analysis; determination of the degree to which the buying habits of major customers overlap in a given period of time, and identification of what, if any, effect selected product line deletions would have on the total sales volume.

To identify the degree of overlap in buying patterns between the major customers, it was decided that a computerized analysis of Sewanee's 1973

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[12] Management Analysis Center Report, November, 1973.

fabric sales data would be conducted. Table 4 provided initial data on the total number of fabrics purchased by each of the top ten customers. The available data was represented as a matrix of fabric purchases by customer, with summary data on the number of fabrics purchased by multiple customers provided. The final results,presented in Table 5, for 1973 indicated that there was very little overlap in buying patterns among the top ten customers. Fifty-seven percent of the 227 fabric patterns purchased by the top ten customers were bought by only one customer. Subsequent purchases by multiple customers trailed off rapidly, with no single fabric being purchased by more than six customers.

For the expressed purpose of ascertaining the contribution of individual fabric sales to Sewanee's top ten accounts, the fabrics bought by these customers were ranked according to their sales volume. The results demonstrated, exhibited in Table 6, quite clearly that Sewanee's broad product line may indeed be far too broad. Of the offerings made to these top accounts,68 of the 227 fabrics sold comprised 90% of the total sales volume to the top ten accounts. In terms of percentages, 30% of the fabrics purchased by the top ten customers contributed 90% of the sales volume of these customers.

The significance of this analysis can only be realized when it is related to the ultimate objective, that of devising an integrated production planning and control system for Sewanee. The fact that Sewanee's production resource allocations are strictly demand-responsive, coupled with the broad offering suggests a major reason for Sewanee's inability to schedule its productive capacity in an efficient and effective manner.

Simple analyses, such as the preceeding, provide management with a tool for deciding where problems may exist in the product line with respect

TABLE 4. SUMMARY CUSTOMER PURCHASING STATISTICS FOR SEWANEE'S TON TEN ACCOUNTS*

CUSTOMER NO.	TOTAL '73 SALES (YARDS)	NUMBER OF STYLES PURCHASED BY CUSTOMER ('73)
1	2,067,000	87
2	2,024,000	53
3	246,800	44
4	485,600	31
5	254,200	43
6	268,700	21
7	406,500	30
8	443,800	38
9	677,400	40
10	267,900	27

*By Dollar Value

TABLE 5. FABRIC STYLES PURCHASED BY MULTIPLE CUSTOMERS

CUSTOMER'S PURCHASING AN INDIVIDUAL FABRIC STYLE	NO. OF FABRICS
1	130
2	45
3	27
4	15
5	7
6	3
7	0
8	0
9	0
10	0

TABLE 6. FABRIC VOLUME ANALYSIS FOR THE TOP TEN ACCOUNTS

CUMMULATIVE # OF FABRICS	CUMMULATIVE % OF FABRICS	CUMMULATIVE % OF TOP TEN SALES
10	4.3	45
20	8.7	60
50	22.0	83
100	43.5	97
227	100.0	100

to volume. Clearly intermittent mill changeovers for the production of small volume fabrics is undesirable; hence, some means of selectively identifying fabrics that are potential problems is needed.

The following section will again deal with historical data, but the emphasis is on product line data rather than customer oriented information.

3.5 Historical Sales Analysis

The previous section attempted to deal with the sales data that could be directly attributed to a customer. In contrast, the present section will be based on an analysis of historical data available to Sewanee with little or no consideration of the customer relationship. Specific areas to be investigated include an analysis of historical sales data in the aggregate (total sales), by product line, and by major styles within product lines. Further detail in the analysis of past sales performance can be gained by investigating the relationship between warp and yarn useage and the volume of sales. The implication of this data for scheduling and inventory control applications will become evident after the analysis. A final area of discussion will center around the relationship between the distribution of sample swatches and the expected level of sales activity.

The direction in which this chapter leads should not be construed as an attempt to forecast sales by extrapolation of a mathematical model. Instead, the analysis presented will serve as a basic input which, when coupled with management's judgement of the other related information in the market place, will allow sound decisions to be generated with respect to expected levels of sales performance. A final point concerns the level of aggregation at which the available sales data will be examined. For purposes

of this evaluation, total sales, major product line sales, and sales for selected high volume styles will be considered.

The following sections discuss the analysis and characterize Sewanee's fabric sales performance at the three levels of aggregation. Additionally, the results of the analysis of fabric sample data will be presented and related to the production planning process.

3.5.1 Analysis of Product Sales Data

There are a number of reasons why analysis of historical data will have direct benefits for an integrated production planning system. Three of the more useful include (1) knowledge of seasonality in the product line, (2) experience with the life cycle curve of particular fabric types, and (3) increased knowledge of the behavior of new products after introduction which can possibly serve to allow mathematical modeling and subsequent sales projection. The analysis of historical data in the initial design phases of an integrated production planning and control system is merely the first step in a process that should be updated continually as new data is collected. Monitoring product performance coupled with a knowledge of the life cycle characteristics of past fabrics can serve to link market information on current sales to expected production requirements over the planning horizon.

The examination of historical data at Sewanee was accomplished by graphical representation of the available information. Unfortunately, actual demand data was not available, so shipments were used as a surrogate. Graphical analysis of the historical data base indicated further that the produce life cycle of many fabrics was extremely short;and hence, it was

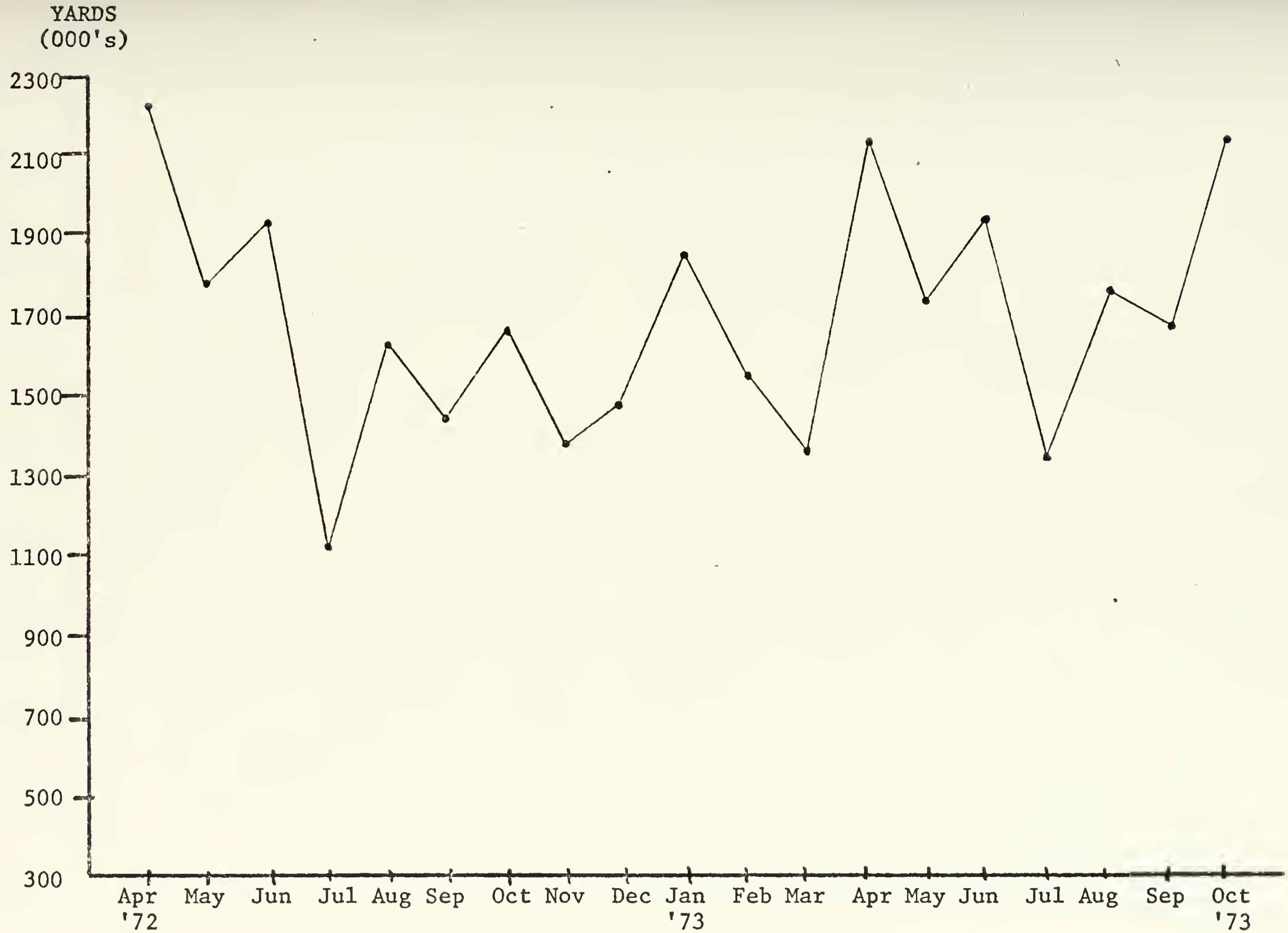

FIGURE 6a. TOTAL MONTHLY SALES AT SEWANEE (APRIL 1972 THROUGH OCTOBER 1973).

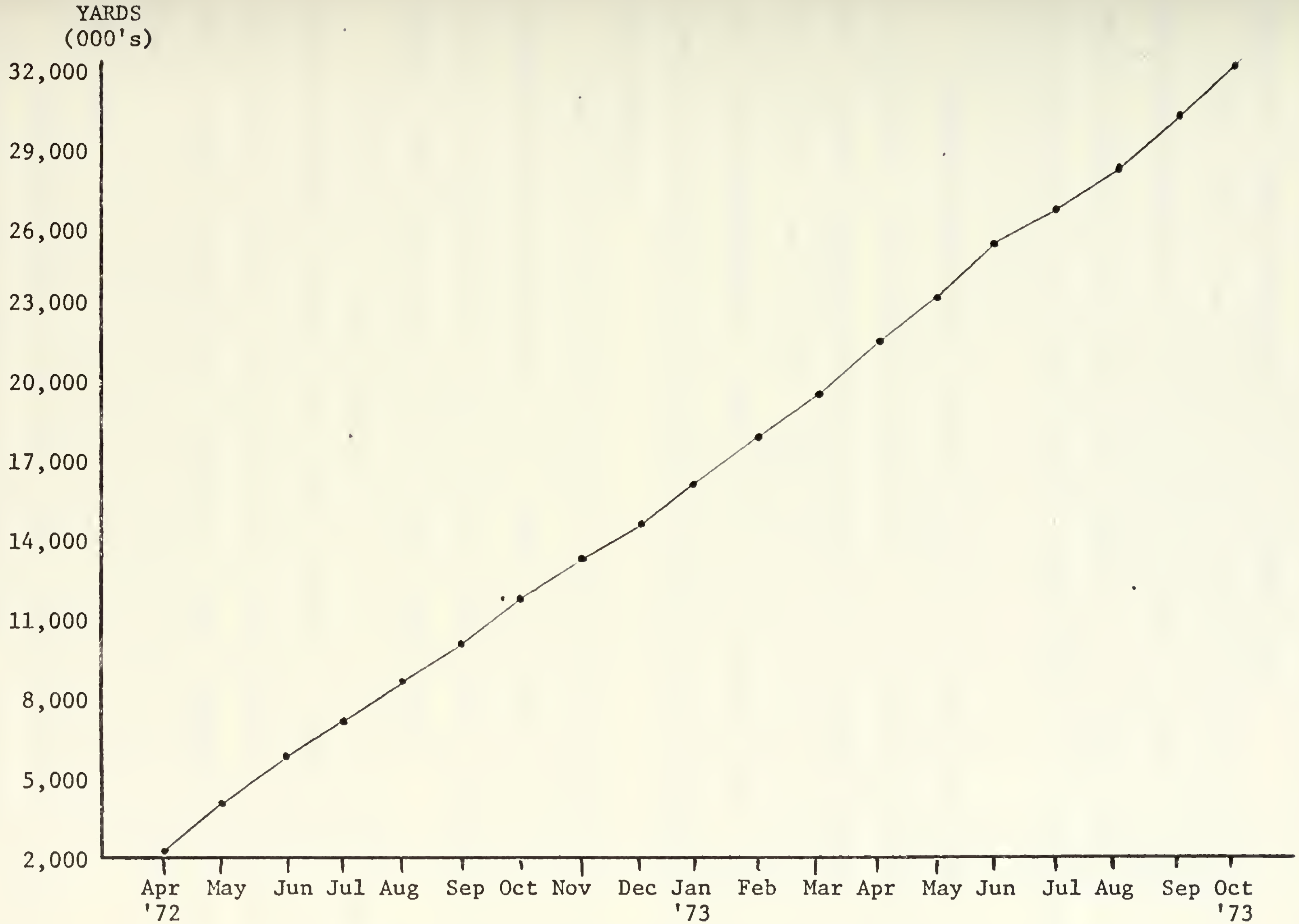

FIGURE 6b. CUMMULATIVE REPRESENTATION OF TOTAL MONTHLY SALES AT SEWANEE.

suspected that mathematical models based on demand data would be of limited value for initial consideration as a planning input.

Total sales at Sewanee have climbed dramatically in recent years. The available information for 1972 and 1973 is plotted by month in Figure 6a and in cumulative form over time in Figure 6b. The indications are that total sales have risen in 1973 and that there appears to be no seasonality in the total sales data.

The link between total sales volume and the production planning process is primarily at the capacity planning level. The data examined suggests that the more appropriate form for modelling and predictive purposes is the cumulative representation. The value of sales data at this level should not be over-emphasized in a study of the scope involved here. Rather, it should be taken more in the context of a useful input to longer-term planning functions.

Examination of sales data in each of the six major product groups provided further substantiation that sales are at this level of aggregation, presented cumulatively over time,result in a near linear relationships. Figures7 and 8 illustrate two of the major product areas.

The analysis of major product groups is more closely tied to specific and more detailed planning of the firm's capacity. Specifically, the requirements for looms of various types can be ascertained if the expected fabric volume of each group is available. Hence, information for major changes in loom configuration can be abstracted from sales information at this level.

Considering demand at the style level introduces data for immediate consideration in the production planning process. The analysis of cumulative

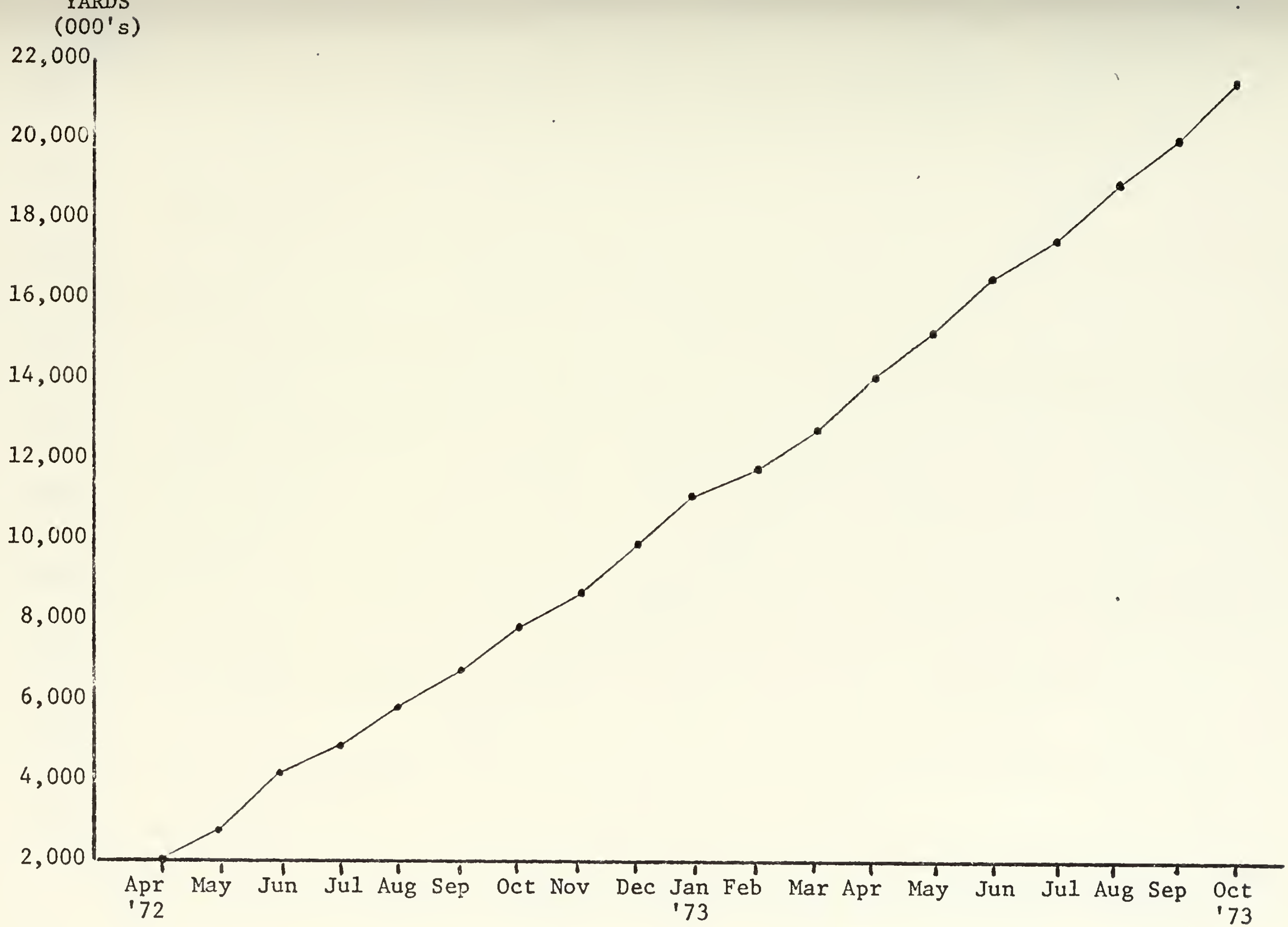

FIGURE 7. CUMMULATIVE SALES FOR POLY FABRICS (APRIL 1972 THROUGH OCTOBER 1973).

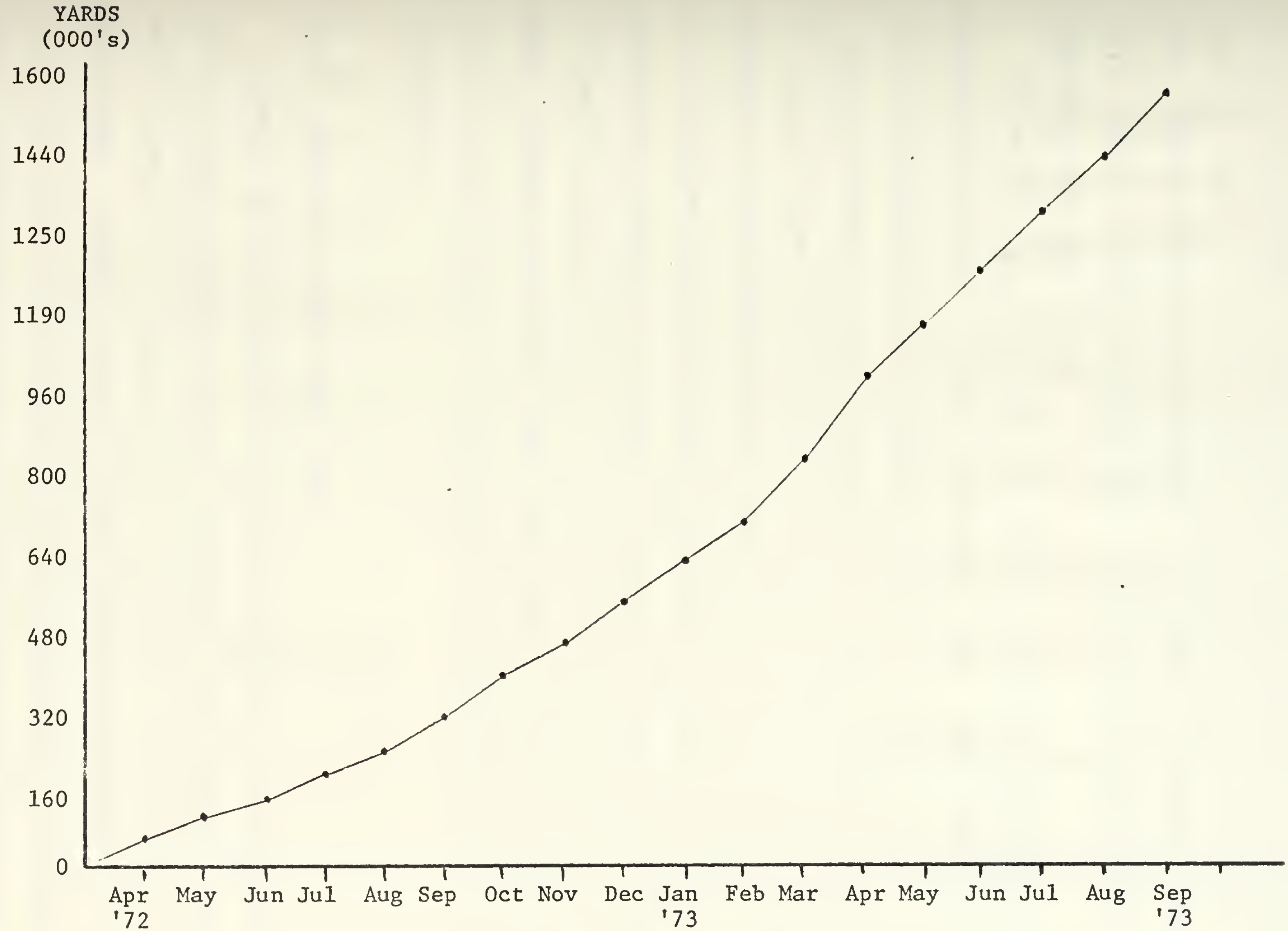

FIGURE 8. CUMMULATIVE SALES FOR PRINT FABRICS (APRIL 1972 THROUGH SEPTEMBER 1973).

plots of major styles in various product lines indicated that they tended to follow linear increasing trends when expressed as cumulative sales over time. Figure 9 illustrates sales data for a typical style plotted over time. Figure 10 represents sales data for the same style plotted as cumulative sales over time.

The value of graphical data presented in the above discussed forms appears to be two fold. First, a knowledge of the product life cycle can aide the planning process by indicating whether the product is at a declining, increasing, or static sales level. Cumulative plots of the sales data appear to have good potential for the application of either exponential smoothing or moving average forecasting techniques. In a normative model of an integrated production planning and control system, the forecast, by mathematical techniques, would play a vital role. In the case of Sewanee less emphasis will be directed at the application of forecasting techniques. Rather, improved use of the product life cycle and general product sales trends will be stressed. The explanation of this approach will be covered in Chapter 4.

3.5.2 Analysis of Product Sample Data

Sewanee currently supplies many of its customers with fabric samples from its sample department located in Morganton, North Carolina. The samples requested by customers are for pre-purchase consideration of a fabric style. Monthly records at Sewanee have been maintained for the years 1972 and 1973 for each style having a sample request during that period, and the totals are saved. It is the objective of this section to relate the sample activity experienced at Sewanee to the expected level of

FIGURE 9. MONTHLY SALES OF THE SOMERSET STYLE (MAY 1972 THROUGH DECEMBER 1973).

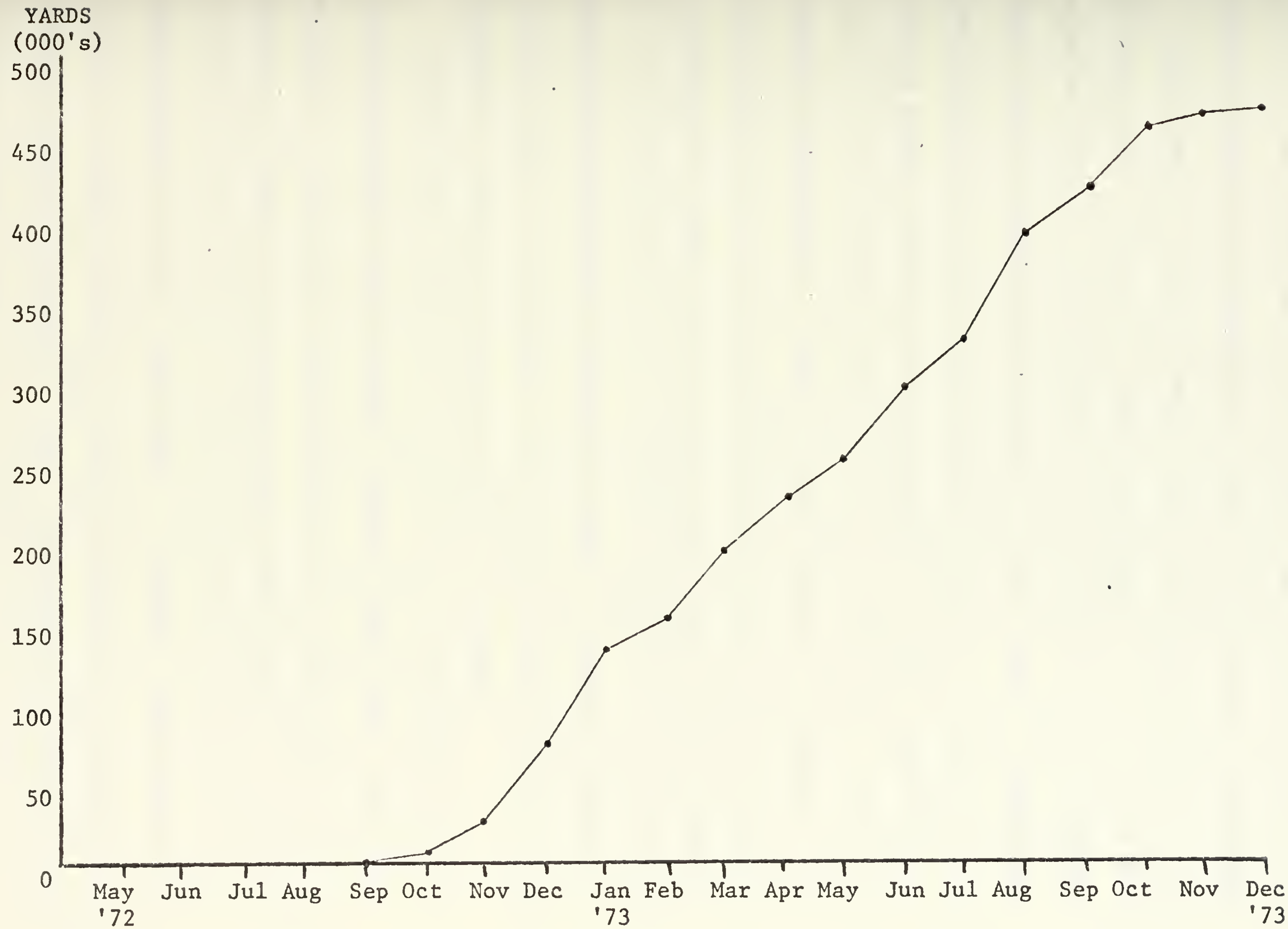

FIGURE 10. CUMMULATIVE REPRESENTATION OF MONTH SALES OF SOMERSET STYLE.

product sales. Undoubtedly, the benefits that could potentially accrue from utilizing this information in a style goods firm are significant.

The problem of relating sample request to expected sales is complicated by two facts. First, the sample distribution to the customer market is segmented with very large furniture manufacturing customers utilizing different sample distribution techniques than their smaller counterparts. The general practice for the large customers involves the purchase of small rolls of fabric (10-40 yards) and subsequent in-house preparations of samples which are distributed throughout their organization. The majority of furniture manufacturers, however, request samples from Sewanee's sample distribution center. The second problem with using sample distribution as a predictor of expected sales involves the timing of sample release. Many of the larger manufacturers have material available for sample furniture preparation several months before the fabric is formally introduced at the furniture market. In addition, a fabric may be offered as an exclusive, therefore it will be distributed to only one customer.

Despite these problems there appears to be considerable potential for correlating sample activities with expected fabric sales. Graphical analysis of several major styles indicates that, in general, fabrics with high sales volumes also experienced high sample activity. In addition to the reflected sales activity, sample requests generally lead the rise in sales performance by two to ten weeks. To further substantiate this supposition, a sample of 39 fabrics randomly selected from Sewanee's fabric line were selected for special study. The sales and sample distribution histories of these styles were collected for the years 1972 and 1973. Total sales and total sample data was accumulated and the fabrics were

ranked by both volume of sales and number of samples distributed. Using the median as the division between high sales and low sales, high sample activity and low sample activity, there was a very even distribution of samples about the median as Table 7 indicates.

To further test the relationship, the list of fabric styles was again ordered by volume with the corresponding sample total carried along during the process. The sample correlation coefficient was computed and found to have a value of .76. The indication is that there is a significant correlation between sample activity and sales volume over the life of a fabric style.

The complete analysis of the available sample data and construction of a predictive model was not the purpose of the initial study. Rather, the review of the information source and its possible contribution to the integrated production planning and control system were more the emphasis of this effort. Specific areas where the sample data needs improvement include the assignment of some reference to the customer's size. Ideally, a record could be made of the purchaser. Improved information on the fabric rolls purchased by large customers that are intended for market introductions and sample distribution within the furniture industry should be maintained as well. Needless to say, the input of a reliable leading indicator of this type into a production planning system for a short-lived product could be invaluable.

The initial sections of this chapter have outlined the product market, customer relations, and historical data that Sewanee has available for planning purposes. The remainder of the chapter will be devoted to assessing the current internal operation at Sewanee, with the ultimate objective

TABLE 7. ANALYSIS OF FABRIC SAMPLE ACTIVITY

		SAMPLE ACTIVITY HIGH	SAMPLE ACTIVITY LOW
SALES VOLUME	HIGH	16	4
	LOW	4	15

being the isolation of major product areas and information sources that will be attacked and utilized respectively in the development of a proposed production planning model for Sewanee.

3.6 Material and Information Flows

3.6.1 General

Sewanee works essentially on the principle of producing to customer orders. A number of good reasons support this philosophy. First is the style-consciousness inherent in the industry. New fabrics can grow to occupy a large share of the product mix in a relatively short period and similarly highly successful fabrics and product lines are apt to experience precipitous declines. It is most difficult to accurately measure consumer tastes for various fabric styles and colors before their display on showroom floors. Although some feel for acceptance is obtained at the regional "markets," such conclusions must be regarded as tentative. Ultimate product acceptance hinges on consumer scrutiny. For these reasons it is held that "forecasting" of product demand by style is simply not practical. On the other hand at a more aggregate level (such as for an entire product line) some gross predictions may be made. However, it is still a guessing game as to what the mix of patterns within a particular product line will be.

Producing to order is facilitated if a four to six week backlog of orders is maintained. Recalling that the production cycle is about four weeks from scheduling of yarn production through shipment to the customer, it becomes clear that when backlogs dip below four weeks the mill may be forced to drop looms off production just to maintain a backlog sufficient

to link its various operations. Maintaining such a backlog is usually not a problem, although cyclical business slumps - such as the one currently being experienced - do cause concern.

It is interesting to observe that despite a backlog of four to six weeks, scheduling of weaving operations is done on both a daily and weekly basis. The weekly scheduling is primarily an aggregate effort while the daily scheduling assigns production of particular orders to specific looms. These concepts will be elaborated on shortly but the important point to be recognized at this juncture is that the scheduling time horizon is short relative to the existing backlog of orders. As such it is not uncommon to observe numerous expensive changeovers in production operations.

3.6.2 Overall System Flow

The general flow of information and material through the system is shown in Figure 11. Orders are received and processed by customer service where a customer due date is assigned. This date reflects the desires of the customer regarding delivery and includes any special instructions such as "do not deliver before February 1." The order proceeds to production control where a "mill date" is assigned. The mill date reflects what production control feels is the appropriate time frame for completion of the order. Production control attempts to assign a mill date that agrees with the customer due date, but this is not always possible given existing backlogs, material availability and other priorities. Data processing (EDP) receives, key punches, and enters the order via batch mode into the computer system. The order is processed into the open orders file and a confirmation notice and number are generated and sent to the customer acknowledging the order, indicating customer due date, and mill date assigned.

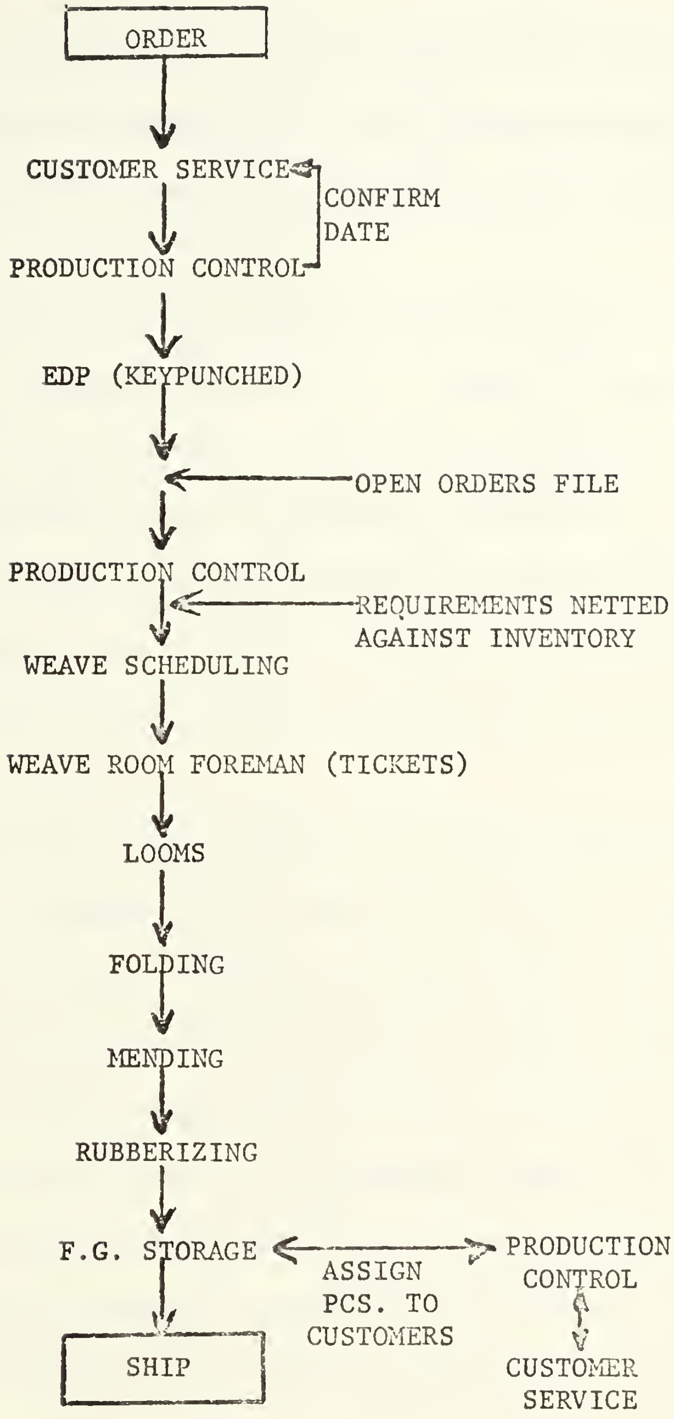

FIGURE 11. GENERAL FLOW OF INFORMATION AND MATERIAL.

A series of computer programs generate assorted reports for production control which tell of impending requirements for yarn and yarn components. Requirements are netted out against inventories on hand and yarn requirements are planned for.

Weave scheduling takes place on both a daily and weekly basis as mentioned earlier. The daily scheduling results in the manual issuing of "weave tickets" to the weave room foreman. This is the authorization to weave specified fabric styles and colors in assigned quantities on specific looms. The issuing of weave tickets generates much additional activity not shown in the daigram. Such activity includes the gathering and delivery of appropriate "fill yarns" from the warehouse to the weave room.

With weave ticket in hand the foreman insures production of the appropriate fabrics during the day. Weaving of an order is followed by several "finishing" operations such as folding, mending, and rubberizing. The completed product is then sent to finished good storage to await shipment. An interesting aspect of the process is that as an order is woven it is not identifiable with a particular customer. For example, several orders for a fabric called Carson Red may be scheduled during a days operations. These orders may be from several different customers or all from the same customer. Nonetheless as the weaving and finishing operations take place the fabric processed is not assigned or identified with any one or all of the customers whose orders generated the production.

Assignment of "pieces"[13] of fabric to customers takes place only after the finished product is in finished goods storage and ready for shipment.

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[13] A "piece" of fabric is the basic unit of production and is approximately 55 lineal yards.

This procedure allows customer service the flexibility of assigning completed pieces to customers irrespective of the order generating the production. In addition it provides a means for allowing priority shipments to special customers. In short, production for an early dated order is diverted to fulfill the requirements for a priority shipment to another customer. The order with the early date must then await additional production of the fabric in question.

This concludes the general description of information and material flow. In the next section we examine the manner in which the various functions are undertaken and some of the problems associated with present operating procedures.

3.6.3 Order Entry and Processing

We have alluded in several places to the process of scheduling. Indeed we have recognized that scheduling takes place at several levels, as witnessed by weekly and daily scheduling. In fact, scheduling is perhaps the most crucial issue to the production control area as it now exists. It is a dynamic process that starts when an order enters the mill and continues until production is completed. This is not intended to imply that all orders are continually being scheduled and rescheduled, but rather that the scheduling process itself involves many uncertainties and as such may be viewed as a dynamic series of events.

When an order enters the mill we have seen that the customer service department edits the order, transcribes it onto appropriate internal forms, and indicates customer due date and other special instructions as appropriate. Next production control, specifically the weave schedulers,

assigns the pieces represented by the order to production in a given "weave week." To this week is added two additional weeks for processing the fabric through finishing departments and to finished goods storage, and the resulting date is quoted as the mill date - the date production control estimates the completed order will be ready for shipment. But how is the appropriate weave week determined for an order that has a requested customer due date ten weeks away?

In arriving at the weave week to be assigned for production of an order, production control allows two weeks for weaving, finishing and preparation for shipment, and two weeks for the making of component yarns. So as a first try the weave schedulers work backward two weeks from the customer due date and check to see if available loom capacity exists in that time period. If so, a mill date is assigned that agrees with the customer due date. If on the other hand the desired week for weaving the order is booked to capacity an alternative weave week must be found. In some instances capacity may exist in an earlier week. In others, the order must be woven at a later than desired date,resulting in a mill date that is past the customer due date.

This initial scheduling process is illustrated in Figure 12. It makes an implicit assumption that all required yarns can be made available by the scheduled weave week. This assumption does not always hold and as a result implies the dynamic nature alluded to earlier.

3.6.4 Order Explosion

Having received a mill date, an order is key punched, entered into the computer system and processed into the open orders file. A series of

- SCHEDULE EACH LINE ITEM ON EACH ORDER INTO NEXT AVAILABLE WEAVE WEEK
- QUOTE DELIVERY 2 WEEKS AFTER NEXT AVAILABLE WEAVE WEEK
- ASSUME YARNS CAN BE AVAILABLE BY SCHEDULED WEAVE WEEK

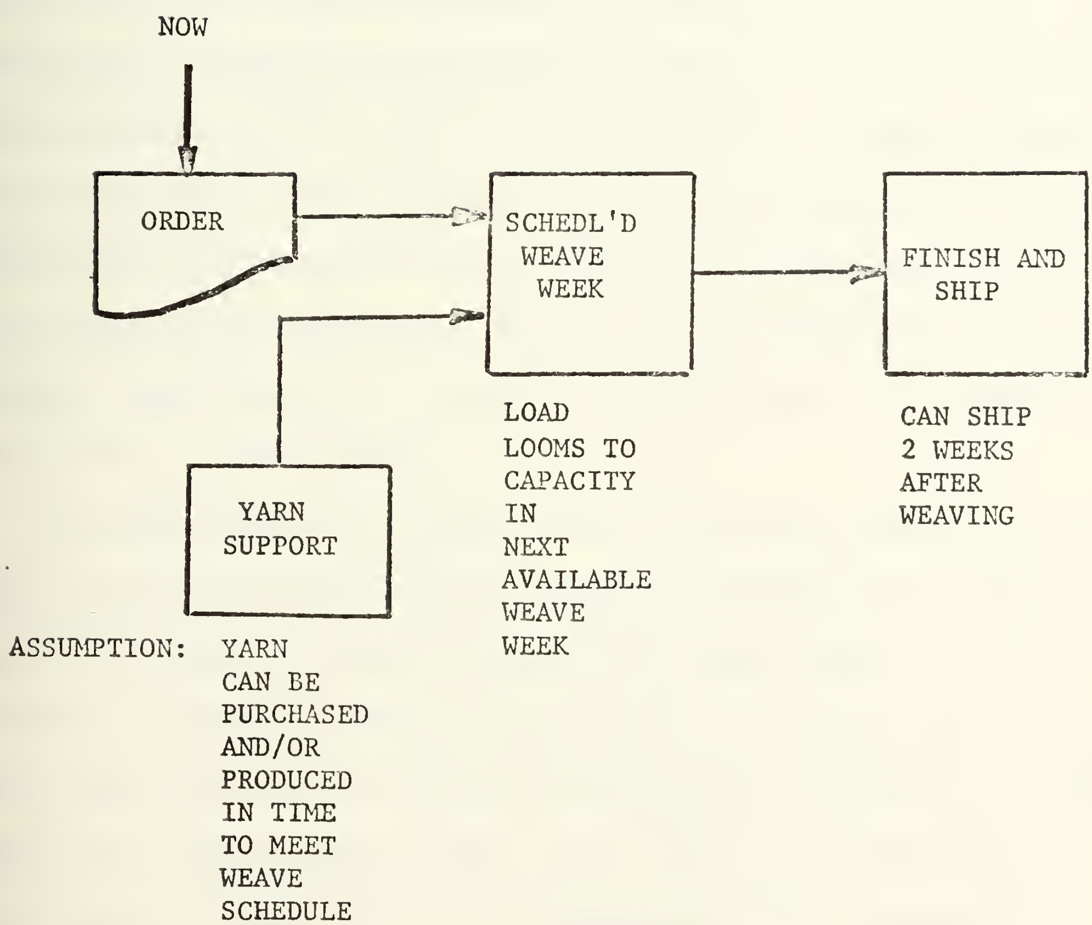

FIGURE 12. INITIAL SCHEDULING OF ORDERS.

programs then processes the open orders file to determine the material requirements to be placed on the mill. This procedure is illustrated in Figure 13.

Net unwoven orders is determined and through various explosion routines these orders are broken down into component yarn requirements by type and by time period (weekly). A report is generated which shows this yarn explosion of unwoven orders.

Yarn requirements are compared against yarn inventory and a report is produced showing current yarn inventories and net requirements by future weeks. This report is used by several departments that must coordinate their activities to insure availability of materials when needed. Yarn scheduling, beaming, purchasing, and production control are all involved in determining what is or will be available and what changes in schedule may be required by the present and projected load on the mill. Again we observe that the assumptions made in assigning a weave week and mill date to an order may be invalidated at this point, necessitating scheduling changes. Such changes will generally be reflected in the assigning of new mill dates to certain orders.

The construction of a fabric involves two basic components. Warps are beams of yarn that are fed into the loom continuously. Fill yarns are yarns fed through or across the warp yarns as the latter are pulled through the loom. In simple terms one might think of the warp as the lengthwise yarn components, and the fill yarns as the width or crosswise components of the fabric. Many different fabric styles and colors utilize the same basic warp or warp "pattern," but have different fill yarn components. We find therefore many fewer warp patterns, (approximately 400 total), than fill yarn types (several thousand). The warp is a key element in the scheduling

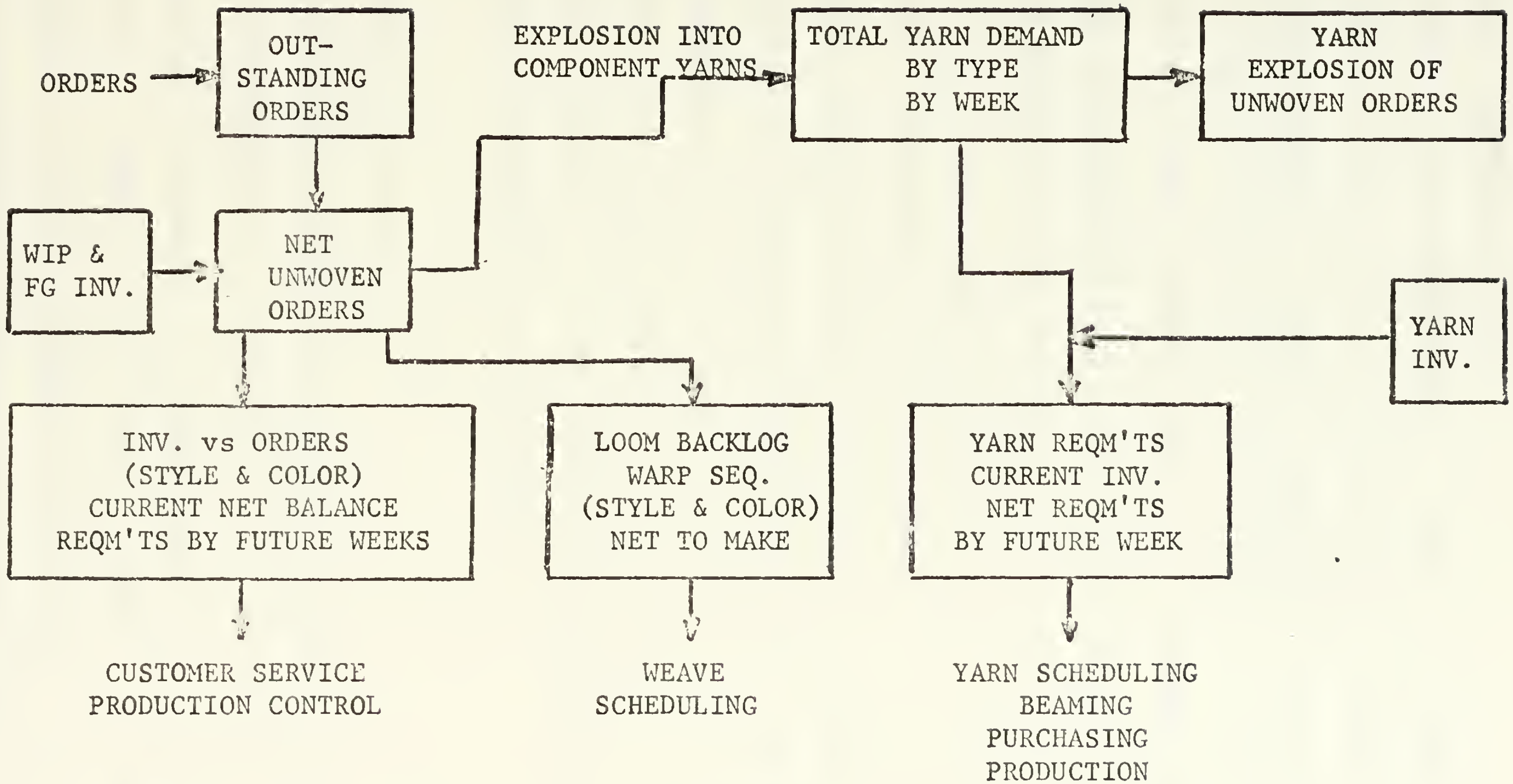

FIGURE 13. ORDER EXPLOSION.

effort and the scheduling of warps to looms is in fact the first step in the more detailed scheduling process.

In addition to yarn requirements, a report is produced which lists the unwoven orders by warp type. The backlog by warp sequence report is used by the weave schedulers to "balance" production in the sense that the number of looms allocated to each warp pattern is intended to yield a given leadtime for the class of fabrics using that particular warp pattern.

Finally an Inventory-Versus-Orders report is generated showing the current net balance of every style and color in the product line and the requirements by future weeks for these same items. This report is occasionally used by customer service in the assignment of pieces to customers and by production control for general planning and information purposes.

We have so far observed the mechanics of order entry and processing, initial assignment of a mill date, determination of yarn component requirements through order explosion, and the generation of several supporting documents (reports). We next examine the procedures by which scheduling of orders at this level is accomplished.

3.6.5 Weekly Weave Scheduling

The weekly weave scheduling procedure in effect sets constraints on the daily scheduling to be accomplished at a later stage. It does so by assigning warps to looms for the scheduling horizon. This process is accomplished on Wednesday of each week and applies to weaving operations to be conducted the following Monday through Friday. The considerations relevant to the decisions involved are illustrated in Figure 14 and discussed below.

CONSIDERATIONS

- WHAT WARPS ARE OVERLOADED NEXT WEEK BECAUSE OF PREVIOUS SCHEDULE BEING MISSED?
- WHAT WARPS NEED ADDITIONAL GOODS SCHEDULED?
- WHAT CHANGEOVERS ARE NECESSARY TO MAINTAIN SCHEDULE?
- WHAT YARN SHORTAGES DEMAND RE-SCHEDULING IN WEAVING?

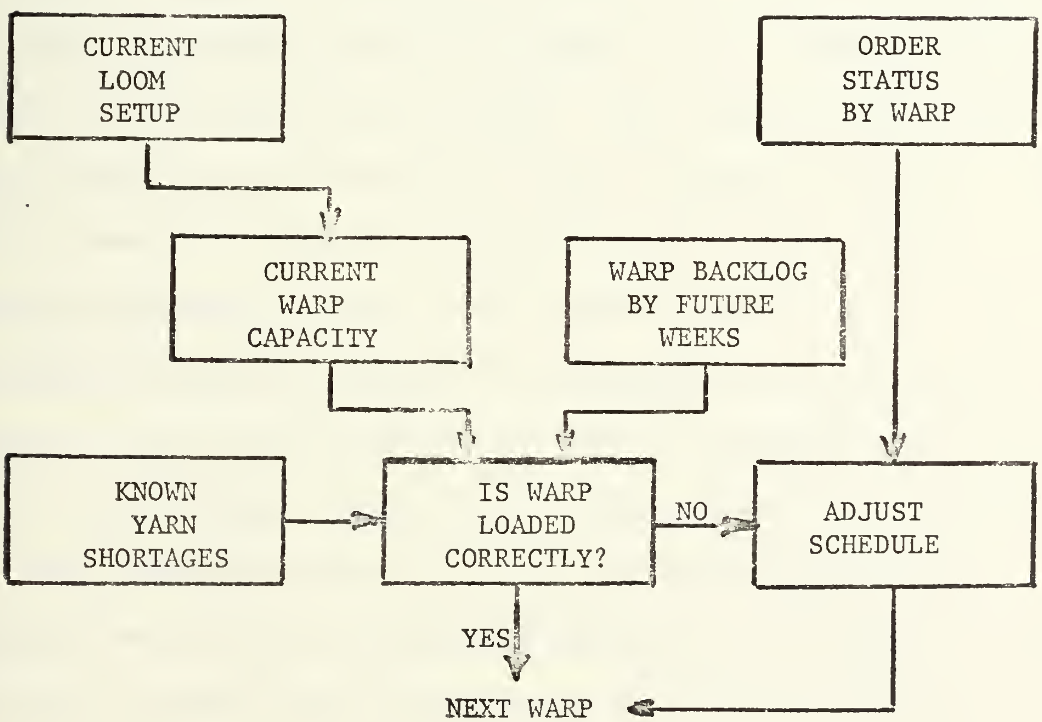

FIGURE 14. WEEKLY WEAVE SCHEDULING PROCEDURES.

Several preliminary comments are in order. First, we are assuming a fixed capacity for the scheduling horizon, i.e., we have only a specific number of looms to work with for the product or sub-product line under consideration. Second, warp patterns are presently in operation with each loom, although a single warp pattern may be in use on more than one loom for high volume fabric styles. To change from a warp pattern that is in production to a different warp pattern is very time consuming. On the other hand, to replace a warp pattern with another of the same type is a much simpler operation and requires minimal production downtime. The key consideration for scheduling of warps,then,is to minimize the number of changeovers from one warp pattern to a different warp pattern.

Referring again to Figure 14, we see that the first consideration is the current loom set up and warps assigned to those looms. The remaining "capacity" of each warp must be gauged. This involves estimating how many yards of fabric can be woven from the yarn remaining on the warp. Next, notice is made of the "load" on looms with various warp patterns. Is there too much production scheduled for a particular warp pattern? Which warps need additional goods scheduled? Are changeovers for warps going to be necessary to meet the anticipated production requirements for the following week? Do yarn shortages exist and will they necessitate re-scheduling?

These questions and others are all relevant considerations in determining the warp set ups for the following week. One additional consideration that deserves special attention is the warp pattern backlog by future weeks. Close scrutiny is paid to this EDP report so as to insure the proper number of warps of each warp pattern are in operation to meet projected increases or decreased in demand for various fabrics styles. Again the goal is to minimize the number of changeovers experienced. Thus it may be

appropriate to produce in next week's schedule an order due in four weeks for a style and color requiring a warp pattern that has only infrequent useage, i.e., it may pay to carry that order in inventory for several weeks rather than incur an additional warp setup at a later date.

The procedure we have attempted to describe is clearly a tedious one. Surprisingly enough it is performed manually by one individual in consultation with several other persons. Because of the many considerations involved, schedule changes are made weekly in the mill date of many orders. Here again we find support for our earlier statement that the scheduling process is of necessity a dynamic one.

Although a clear understanding of the process may be difficult to grasp from this brief overview, two crucial points should be noted. First, the warp scheduling process sets a constraint for the daily weave scheduling process. Secondly the dominant concern in warp scheduling is the minimization of changeovers.

3.6.6 Daily Weave Scheduling

At the daily weave scheduling level we reach the final stage of the scheduling effort. The constraints are those set by the weekly weave schedule, those warp patterns which are assigned to looms for weaving in the current production week. In addition the daily weave schedule is constrained by fill yarn availability. This process is illustrated in Figure 15.

As in weekly scheduling the first consideration is to determine what is left on the loom in terms of warp capacity. The daily weave scheduler then turns his attention to two EDP reports entitled "unissued orders by due date; and "unissued orders warp summary." The former report is relied

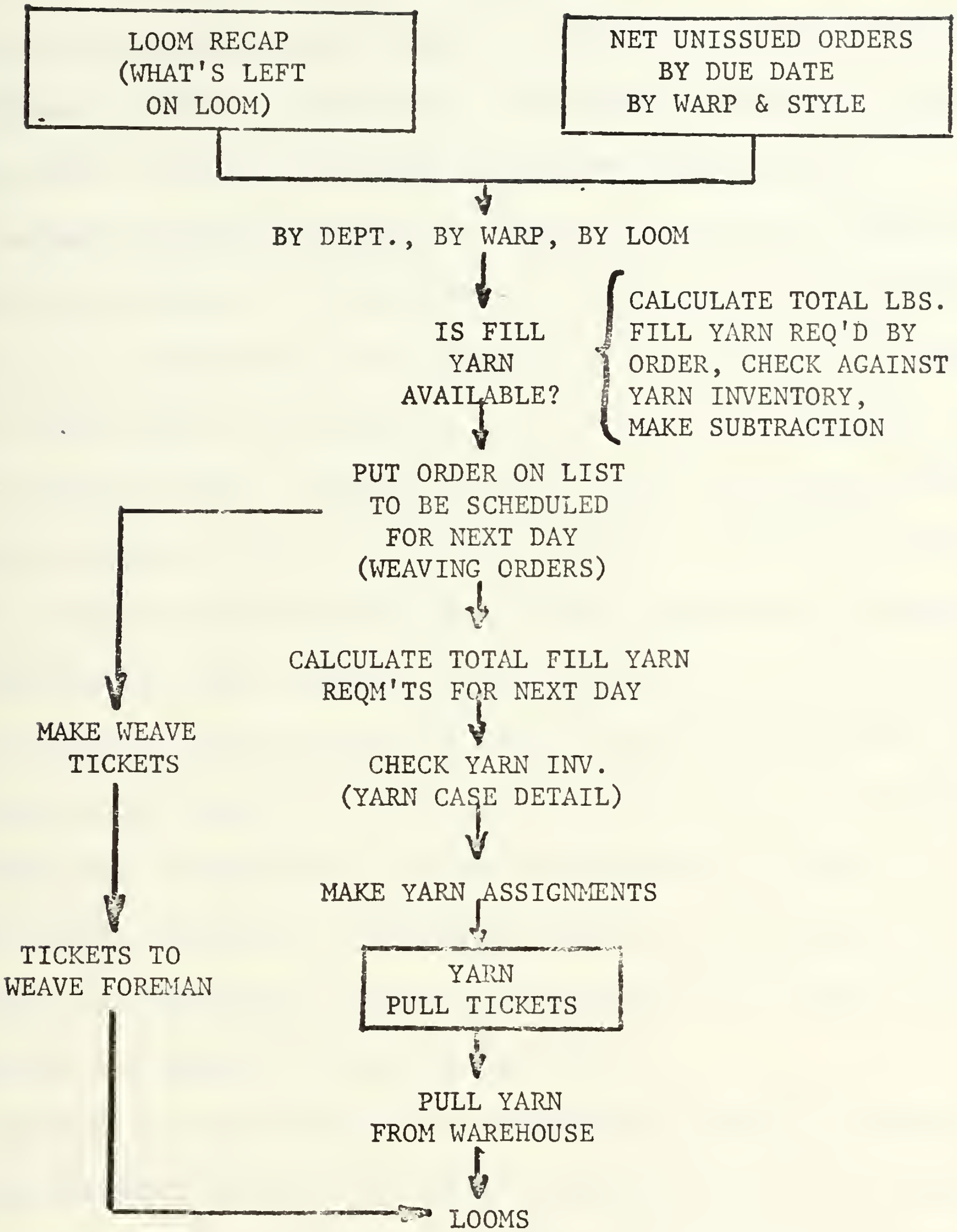

FIGURE 15. DAILY WEAVE SCHEDULING PROCEDURES.

on for the most part. It lists chronologically by due date those orders that have not been scheduled for weaving. Those orders overdue are listed before those due in the current week. First effort is made to schedule overdue orders, followed by current orders and future orders.

The weave scheduler proceeds to schedule one order at a time from the unissued orders report. In scheduling each such order he must check to see if fill yarn is available in the proper quantities (lbs.) to weave the order. This requires the scheduler to reference a yarn inventory report which is updated daily. Because any given fabric may require several different fill yarns it is clear that the scheduling of only one order can become a very time consuming process. When we compound the problem by considering that the daily scheduler will schedule perhaps several hundred orders, it becomes obvious that the manual scheduling procedure at this level can be and indeed _is_ a full-time job. The daily weave scheduler must deal with other considerations not listed explicitly in Figure 15. Such issues include attempting to take style and color contiguities into consideration when scheduling orders. By so doing he can reduce fill yarn changeovers and thereby increase productivity.

Returning to our illustration of the daily scheduling procedure we see that the available looms are loaded to "capacity" with orders from the unissued orders report. The orders selected for production are then manually transcribed into "weave tickets" which are delivered to the foreman of each production department. Simultaneously these orders are aggregated in terms of their fill yarn requirements for the next day. When this effort is completed the fill yarn requirements are gathered from the warehouse and delivered to staging areas in the various weaving departments. This is accomplished on the night shift. Note in the diagram that for each case

of yarn taken from inventory a "yarn ticket" is pulled. All such yarn tickets are delivered to EDP and an updated yarn inventory report is generated for use in the next days scheduling of orders.

Finally, we have the weave tickets and fill yarns arriving at the looms. The weave ticket constitutes the authority to weave the given fabric style and color in the indicated quantities.

3.6.7 Yarn Scheduling

An implicit assumption made so far has been that yarn can be made available to support weaving operations. We have seen that in both weekly and daily weave scheduling reference is made to yarn and warp inventory summaries to ascertain the availability of requisite yarns. It is perhaps apparent that yarn availability is a major constraining factor on the ability of the mill to produce goods. Yarn availability is in turn directly influenced by the availability of both raw materials required to spin the yarn, and outside suppliers to supply finished yarns directly. The joint task of yarn scheduling and purchasing is to insure that yarns are made available as needed.

In Figure 16 we see the decision process followed in arriving at the yarn production schedule for the next week. The level of production requirements is determined from a comparison of usage and requirements information. Production hours for each item are then set. Comparison of present set ups for yarn spinning with the production hours required to support next weeks schedule determines the changeovers necessitated. Raw material availability is ascertained and next weeks yarn production schedule is set.

Ideally, the provision of fill yarns required for production of a week's weaving is done two weeks prior to the actual weaving of the fabric. This

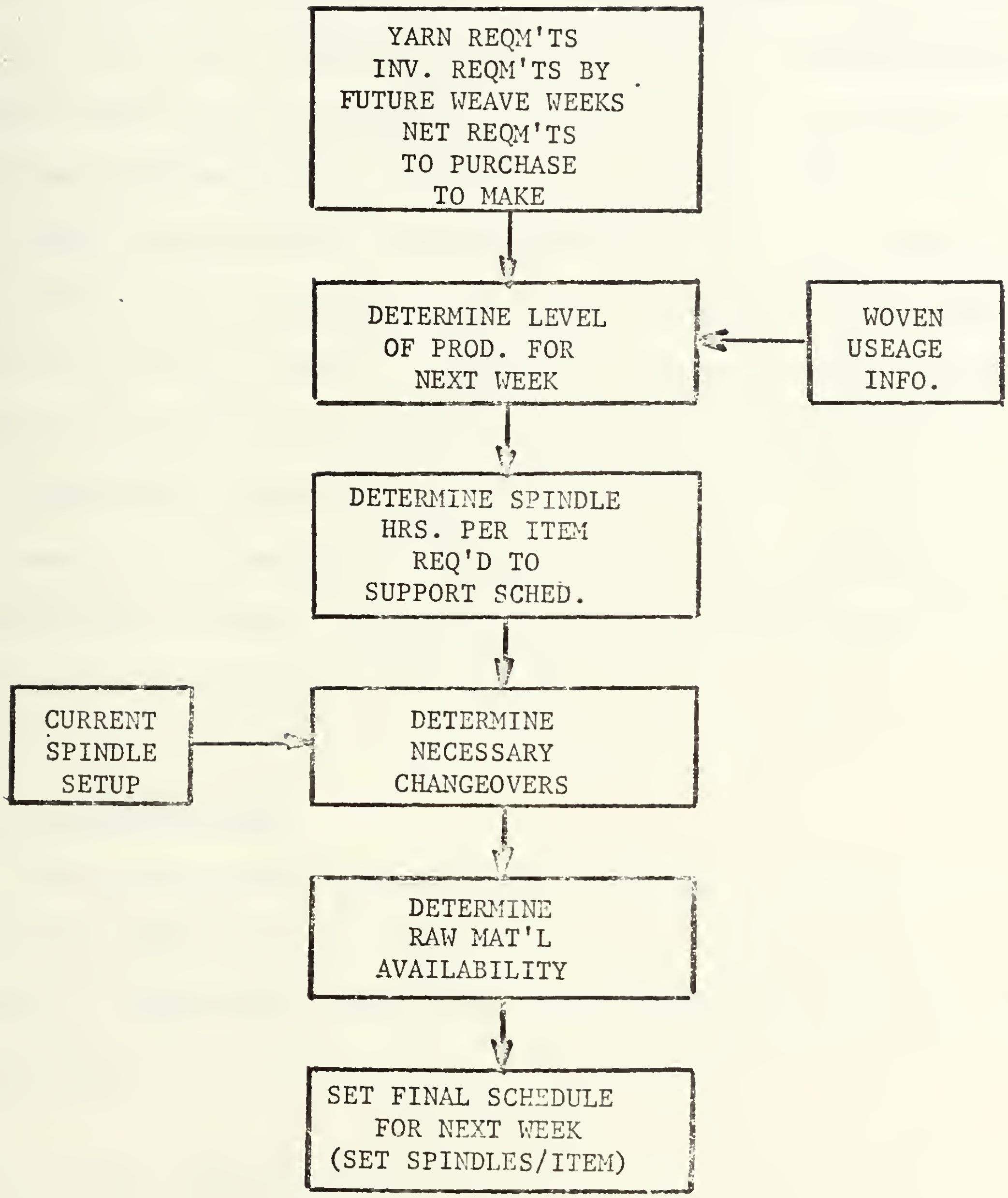

FIGURE 16. YARN SCHEDULING PROCEDURES.

assumes, however, that yarn scheduling is aware two weeks in advance of the detailed production schedule for weaving operations. We have seen that this is not the case, for daily weaving scheduling determines the actual orders to be scheduled for weaving on a day to day basis. Yarn scheduling, then, simply produces yarn to meet what is best anticipated to be the aggregate fill yarn requirements of each successive production week.

There are, therefore, frequent occurences when several yarns required for production of a group of orders are not available. Yarn production is forced to alter its schedule to produce the needed yarns on an expedited basis or the order is simply delayed. With such uncertainties it can become most difficult for yarn schedulers to keep up with weaving demands. This area is a key concern of management and has been receiving increased attention most recently. The problem requires a close working relationship between weave and yarn scheduling personnel.

3.7 Key Problem Areas

As we have progressed through our discussion of information and material flows several areas have been identified as problem sources. In this section we examine more closely these and other problem areas not previously mentioned.

3.7.1 Product Line Diversity

Product diversity has occurred rapidly over the past several years. With such diversity came manyfold increases in the yarns required to support the broadened product line. It became increasingly difficult for yarn scheduling and purchasing to supply in a timely manner the many raw

material and yarn inputs required by weaving operations. Virtually every area from purchasing through finished goods inventory has been forced to live in a more demanding environment. In short the present diversity of the product line has intensified the overall complexity of the mill's operation.

Aggravating still further the problem of product diversification has been a lack of any systematic policy regarding fabric deletion from the product line. A large percentage of the fabrics in the product line show almost no demand history for the past year, yet yarn inventories are maintained to support these products. (Not every such style has its own set of yarn requirements; many share yarn requirements with other more "active" styles).

Sewanee's top management recognizes the problem and has been taking steps to relieve the pressures caused by product line diversity. But product deletion is not easy, since furniture manufacturers are reluctant to have "cut" the selection they offer to their dealers.

3.7.2 Inventories

Inventories can become a problem for virtually any manufacturing firm. For Sewanee this is particularly true. The product line breadth has contributed in large part to the size of present inventories, but is not the sole factor at work. Clearly, increasing the number of yarns held in inventory is bound to require some increases in aggregate inventory levels.

The control system applicable to yarn inventories is such that no distinction is made between yarns with very high usage rates and those with low usage. As a result many small production runs of low usage

yarns are made when infrequent large runs might prove more economical. A private study of 1972 operations indicated that 30% of the labor costs in the beaming department are attributable to set-up changeovers. The control system in essence treats all yarns as equally important when in fact about 10% of the total number of yarns account for in excess of 81% of the total volume usage.[14] Failure to deal with this situation is resulting in excessive inventory levels.

An interesting aspect of the inventory system is the procedure by which fill yarns are issued for weaving operations. Fill yarns are issued in "case" lots. Each case contains many spools of yarn whose aggregate weight may vary 10-20% from other similar such cases. Although an order scheduled for production may require only 30 pound of a particular yarn, an entire case weighing perhaps 80 pounds is issued and the unused yarn is later repackaged and returned to inventory. The attendant problems in such a system are several.

First, when cases of yarn are removed from inventory the case is deleted from inventory records. Unused portions of cases take several days to work themselves back into inventory and onto inventory summaries. As a result, frequent stockouts do occur for yarns which are "in transit" in the materials handling system. Second, accuracy is hampered by the system described. It is not uncommon for an order to be scheduled and fill yarns assigned for picking from inventory only to discover the yarn required is nowhere to be found. Such occurrences require the daily weave scheduler to duplicate his efforts and schedule additional orders at the last minute.

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[14] Management Analysis Center Report, November, 1973.

3.7.3 Scheduling

The scheduling procedure described at length in an earlier section has many associated problems. Not the least of these problems is the fact that the entire process is manual. Although the personnel involved perform excellently within the constraints faced, there is a limit to the number of contingencies the human mind can handle. In the detailed scheduling process alone we have seen that the scheduler must consider all of the following:

- present loom set ups (warps)
- remaining warp capacity on each loom
- warp changeovers to be accomplished in accordance with the weekly weave schedule
- yarn and warp shortages
- priority orders or accounts
- style and color continguities
- unissued orders report
- run length considerations
- other "special" considerations

There are inherent limitations in human manual ability to consider all of the above in a systematic manner and still accomplish the daily scheduling effort.

The time horizon applicable to scheduling at the weekly level is perhaps too short. With a six-week backlog of orders a longer horizon for warp scheduling would be more appropriate. Again, the ability of one man to consider all the relevant possibilities for such a time horizon is limited, suggesting an automated approach might be a viable alternative.

The present linkages between weaving and yarn scheduling are weak. Although much communication exists between those personnel responsible for such operations, problems in yarn availability inevitably occur. Yarn scheduling, although in theory two weeks ahead of weaving, is required to respond on an almost daily basis to produce requirements for weaving operations. Such procedures, although they accomplish the task at hand, are far from ideal.

We have referred in many places to the term "capacity," asserting that looms are loaded to capacity in both the daily weave scheduling and in the initial scheduling process intended to arrive at a mill date. Clearly, a loom must have some readily-measureable productive capacity. In fact this is far from the case. Although looms are rated at a capacity in terms of "picks per hour,"[15] different fabrics require varying numbers of "picks" to weave equivalent yardages. The estimates of capacity used in the scheduling process are far from precise and usually represent the cumulative experience of the scheduler more accurately than the real capacity of the loom.

We have discussed only a few of the many problems associated with the production of fabrics at this textile firm. Our observations lead us to the conclusion that the process is extremely complex and necessitates a thorough planning and control system. Our suggestions for such a planning system are developed in the following chapter.

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[15] A "pick" refers to the weaving of one width or crosswise component of fill yarn. A loom is rated at a given number of picks per hour.

CHAPTER 4.

A PROPOSED INTEGRATED PRODUCTION PLANNING AND CONTROL MODEL FOR SEWANEE

The preceeding chapters have served to present the existing production system at Sewanee, illuminate a number of problem areas, and point out several sources of information that are currently available but have not been exploited. The task in this chapter is one of outlining how the available information can be used at Sewanee and proposal of a normative framework for Sewanee's production planning.

Structural features of the chapter will follow a course of review, model presentation, and amplification of the working concepts embodied in the planned framework. The objective of this approach is to point out the relative value of integrated production planning and control to Sewanee's management.

4.1 Expected Benefits From Integrated Production Planning

Chapter 3 stressed familiarization with Sewanee's internal operations and its product market environment. The points discussed raised a number of issues which merit review. In addition, the problem identification will facilitate the explanation of the benefits expected to accrue with the move to integrated production planning and control at Sewanee.

Four major areas will be stressed in the analysis of expected benefits from the proposed system. These include:

1. Improvement of the management decision process involving the allocation of productive resources as a result of better utilization of information sources.

2. Improved customer service.
3. Improvements in the scheduling process that ultimately result in lower production costs.
4. Improved control of inventory levels at all points in the system.

The following paragraphs attempt to relate each of the expected improvements to the key factors crucial to their attainment.

It is a basic responsibility of production management to involve itself in the planning function. Probably the single most important contribution to be expected from this involvement is the establishment of priorities throughout the production system. Priorities at all levels in the system determine not only what is made, but also when it is made. Implicit in the establishment of priorities is the necessity for decision - making; and hence, the need for accurate and useful information upon which to base the required decisions.

The basic question of where the information is to be acquired for decision-making is complex and not easily answered. In Chapter 3 the most common starting point, historical sales and customer data, was explored. In the following sections, information available from Sewanee's sales force and their research and development group will be considered.

Central to the success of production management's decisions, however, is the quality of the available information. Furthermore, any proposed system for improvement of this task must of necessity account for the way in which management receives and uses the available information to both plan and control the production process. This is to say, management's use of the information may range from highly subjective to predictive modelling.

The second major area in which benefits can be expected to accrue is in the service provided to the market. There are two ways in which this improvement can be realized. First, reference can be made to the speed with which the mill is able to respond to customer needs. A second, inseparably linked benefit, would involve the credibility enjoyed by Sewanee in its customer relations. While lead times may be long from the furniture manufacturers point of view, there is little he can do other than seek alternative suppliers. Under the current market conditions, he is, in most instances, forced to accept the lead times quoted. The problem of credibility arises, however, when after promising a delivery, Sewanee fails to inform the customer of changes in the delivery schedule or excessive tardiness on order delivery.

With the introduction of integrated production planning and control Sewanee can potentially enjoy improvements in both of the above mentioned areas. The production planning and control effort will be more efficient in its utilization of productive capacity. Hence, given constant demand, the lead time on product deliveries will decline. Improved monitoring capabilities will aid in building customer credibility. Quoted dates can be altered and reported with greater ease.

The third area of improvement, scheduling, is of prime importance in supporting improved customer delivery performance. It is the central purpose of this thesis to impress on Sewanee's management decision-making the importance of scheduling. In this particular production process, scheduling carries a multi-tier connotation. The primary concern, initially, is the development of the master schedule, the expected production requirements of the firm time phased over the planning horizon. Knowledge of end-item requirements facilitates planning for intermediate components

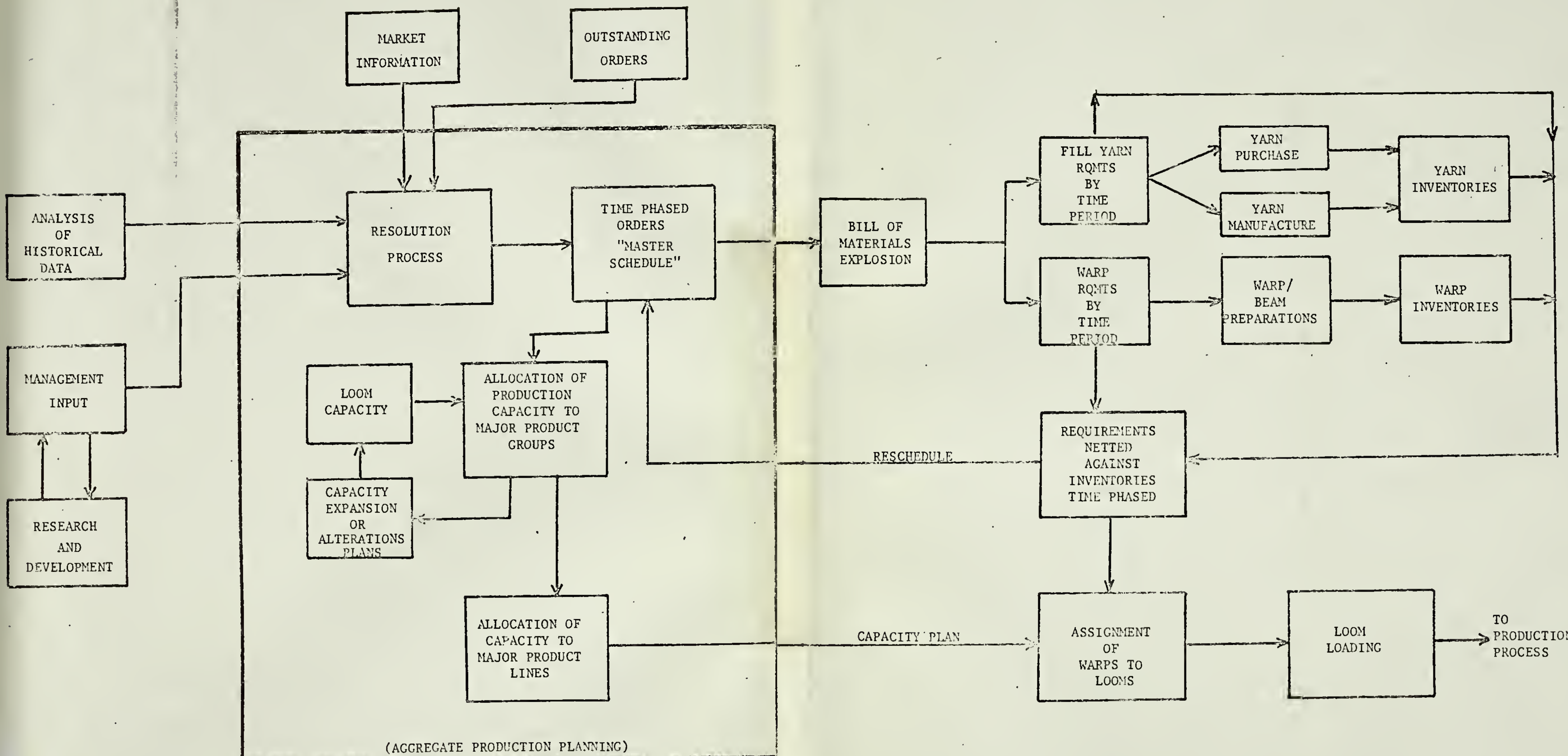
throughout the system; and hence, the scheduling of subordinate production and procurement processes. In Sewanee's case, this will particularly affect the yarn production, raw materials requirements planning, and the efficient and effective loading of looms. In essence, the objective is simply a balanced production process that is effective and efficient in achieving production management's goals.

Inventory control comprises the final area of expected gain. Although this topic quite properly might have been included in the scheduling improvements, the area of inventory control is of great enough significance to warrant special attention. Improvements in information flows, more efficient scheduling, and better long-term capacity planning will hopefully result in Sewanee's ability to improve its inventory control at all levels in the system. Furthermore, the condition of imbalance in inventories that currently plagues Sewanee should be alleviated with a shift to requirements planning.

With the expected benefits in mind, the next section will present the proposed approach for achieving these benefits. Within the proposed framework, the information flows will be outlined and their importance to improved decision-making stressed first at a gross level of detail followed by a detailed explanation.

4.2 Details of the Proposed Integrated Production Planning System for Sewanee

Figure 17 illustrates the integrated production planning and control system proposed for Sewanee. The framework diagrammed depicts the process down to the level of style/color assignments to looms. It is, however, the aggregate production planning process, the inputs to it, and the link with


MARKET INFORMATION
OUTSTANDING ORDERS
ANALYSIS OF HISTORICAL DATA
RESOLUTION PROCESS
TIME PHASED ORDERS "MASTER SCHEDULE"
BILL OF MATERIALS EXPLOSION
FILL YARN RQMTS BY TIME PERIOD
YARN PURCHASE
YARN MANUFACTURE
YARN INVENTORIES
WARP RQMTS BY TIME PERIOD
WARP/ BEAM PREPARATIONS
WARP INVENTORIES
MANAGEMENT INPUT
RESEARCH AND DEVELOPMENT
LOOM CAPACITY
ALLOCATION OF PRODUCTION CAPACITY TO MAJOR PRODUCT GROUPS
CAPACITY EXPANSION OR ALTERATIONS PLANS
RESCHEDULE
REQUIREMENTS NETTED AGAINST INVENTORIES TIME PHASED
ALLOCATION OF CAPACITY TO MAJOR PRODUCT LINES
CAPACITY PLAN
ASSIGNMENT OF WARPS TO LOOMS
LOOM LOADING
TO PRODUCTION PROCESS
(AGGREGATE PRODUCTION PLANNING)

the downstream system that is of major concern in this discussion. The following sections will briefly outline the feature of each component of the model. This discussion will be followed by detailed specifics related to the key production planning issues.

4.2.1 Inputs to Aggregate Production Planning

The information directly affecting the production planning process has been categorized as follows: research and development input, management input, historical data analysis, field information, and outstanding orders. The success of Sewanee's integrated production planning and control system rests squarely on the quality and applicability of the information obtained from its environment. To gain a perspective on each of the above mentioned sources, they will in turn be considered in considerable depth. It may be noted at this time, however, that the improved use of the available information appears to be one of the shortest payback areas in the proposed planning system. The aggregate production planning function designed to aid this process is the next area of discussion.

4.2.2 Aggregate Production Planning

The primary functions of the aggregate production planning process can be looked at as an input/output module in the proposed integrated planning system. The following discussion outlines briefly the concept involved and more detailed explanation of each component of the model follows in a later section. The inputs are the information sources and the outputs are a time phased schedule of projected production requirements, the master schedule, and a capacity plan that acts as a directive for actual production scheduling. The components of the module are designed to

first resolve the information related to product demand, both realized and expected, and produce a plan that management feels will best satisfy these requirements in the most effective and efficient manner.

Detailed analysis of the decision basis and reporting process internal to the aggregate production planning module will follow in a later section. The breakdown at each level of resource assignment will be a key issue to resolve. In addition, the ability of the system to respond to imbalance in inventories and productive capacity limitations at intermediate component levels will be reviewed.

4.2.3 Requirements Planning

Requirements planning is simply the projection of the components of the end products identified by the master schedule time phased into the future. The master schedule entries are exploded with the aid of a bill of materials into basic "fill yarn" and "warp" requirements. As is the case with the master schedule, these requirements are time phased into the future thus providing information for the prediction of component inventories over a several week horizon. It is at this point that requirements for components at this level generate demand for production and procurement services at the next lower level.

The ability of the existing system conditions to meet the requirements specified at this time is accomplished by matching available component inventories with the expected requirements. Should the current master schedule prove to be infeasible, because of materials shortages detected when material requirements are netted against inventories, the system provides this information to management thus allowing a revamp of the master

schedule. If the master schedule is feasible to all subcomponent levels, the warp requirements serve as the basis for the loom loading process.

Having planned materials requirements over the planning horizon, the capacity plan and the master schedule serve as a guide for warp assignments to looms and subsequent fabric scheduling procedures.

4.2.4 Detailed Scheduling

The specifics of detailed scheduling follow the requirements planning and loom loading process. The many varied methods for accomplishing specific loading are of interest in this treatment only so far as they are affected by the aggregate planning process.

The preceeding component description has served to link the basic information sources from the market through the planning process in such a manner that specific guidance can be made available for detailed scheduling. Let it suffice to say that the process of detailed scheduling will more likely follow the interest of company management given the closely linked progression from market to production.

4.3 The Role of Information Sources

The various sources of information discussed in the analysis of data in Chapter 3 merit considerable discussion in the detailed analysis of the proposed planning framework. The following sections will outline the procedure to be followed in presenting the information inputs to the planning process.

Reference to Figure 18 indicates that there are four sources of primary information with which we are concerned. These are (1) outstanding orders by time period, (2) field information, (3) historical sales analysis, and

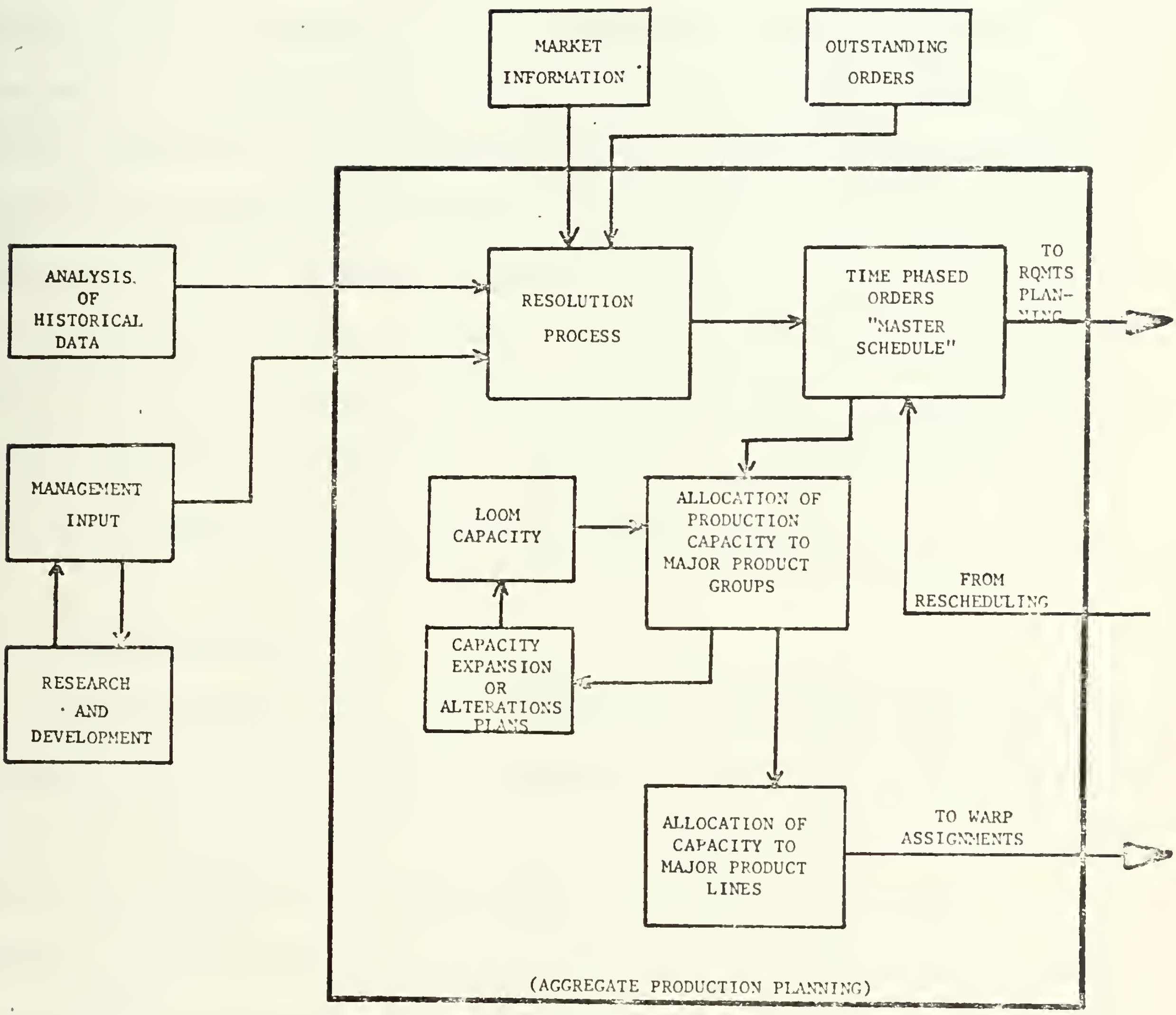


FIGURE 18. AGGREGATE PRODUCTION PLANNING.

(4) management input (which explicitly includes research and development input).

Conceptually, it is important to realize that the outstanding orders by time period is the most "concrete" information source available to management. It tells management exactly what the realized demand for individual fabrics is. The remaining information is much less precise and requires more judgemental evaluation by management. The information from these sources serves to modify the basis of actual orders to the level management expects orders to assume. The flow of information from various sources into the "resolution process" accomplishes this very objective. To further investigate the mechanics of this process each information source will be discussed and linked to the resolution process.

4.3.1 Outstanding Orders

The outstanding orders report is organized to present demand (orders) at several levels of aggregation. The most detailed level is by sub-product lines within major product groups. For each week the orders for all styles within a sub-product line are aggregated and listed on the report. For example, the olefin (poly) group has about ten sub-product lines as shown in Figure 19, and the sum of all orders for styles in sub-product line F in week 5 is 500 pieces. The next higher level of aggregation, major product groups, results simply from adding the elements of each column of the report. Thus in week four the olefin product group has a demand of 4900 pieces. Finally we can move to total demand on the mill for each week. This is found by adding the demands of the three major product groups. The total demand on the mill in week three is 5315 pieces.

WEEK #	1	2	3	4	5	6	7	8	≥ 9

OLEFINS

LINE A	700	900	800	650	700	875	800	800	1200
LINE B	300	400	350	400	280	370	300	425	550
LINE C	150	100	125	175	210	150	165	180	500
LINE D	400	350	375	560	380	420	400	380	700
LINE E	300	350	250	280	360	450	400	210	600
LINE F	560	600	500	480	500	420	600	530	1200
LINE G	340	350	400	410	400	300	325	350	500
LINE H	600	500	600	480	560	575	480	650	800
LINE I	400	350	425	290	360	450	410	370	800
LINE J	550	500	575	475	530	490	500	460	1100

OLEFIN TOTALS	4300	4400	4400	4200	4280	4500	4380	4355	7950

PRINTS

P1	300	200	300	250	225	310	330	280	600
P2	200	180	190	230	175	210	165	210	450
P3	150	180	160	230	180	140	175	190	200
P4	100	80	75	105	90	95	80	70	190

PRINT TOTALS	750	640	725	815	670	755	750	650	1440

EASTMAN

E1	50	70	90	80	75	80	70	65	110
E2	80	100	100	130	110	95	120	100	190

EASTMAN TOTALS	130	170	190	210	185	175	190	165	300

MILL TOTALS	5180	5210	5315	5225	5135	5430	5320	5170	9690

FIGURE 19. OUTSTANDING ORDERS REPORT.

Through use of this report management is able to discern several things. First they are able to use the information in its highest levels of aggregation. If the total load on the mill averages 5400 pieces per week and the mill capacity is in excess of that figure then no apparent aggregate capacity problem exists. However when looking at demand by major product groups it may become clear that the existing capacity allocations to the three product groups is not properly distributed.

For example, 12 looms may be assigned to the Eastman product group, 80 to the olefin group, and 25 to the print and piece-dyed fabric group. If the outstanding orders report indicates that at some point in the time horizon, say four weeks downstream, the demand has shifted so as to require additional looms in the Eastman group and less in the olefin and print groups, then plans must be generated to accommodate the shift. The solution to such problems, however, is far from simple.

Secondly, management is able to detect trends of growth or decline in sub-product lines. If the demand is observed to be growing from an average of 100 pieces per week to 150 pieces per week for a particular sub-product line, it may be necessary to alter the warp assignments to various looms. Conversely if orders are declining, a phaseout of one or more looms may be appropriate.

In addition the total backlog by sub-product lines provides management hypothetical "what if" types of questions. For instance, if demand for a given sub-product line in the olefin group continues its present rate of growth what alternatives are available to management? Is there a need to purchase additional looms or can demand in other sub-product lines be expected to decrease a corresponding amount? When do we need to add loom capacity? Is the growth or decline of given product lines in consonance

with our perceptions or expectations? Simply stated, the outstanding orders report in the format described allows management to perform informal mental simulations of various conditions. Such exercises may not be particularly precise, but they are useful in production planning.

4.3.2 Market Information

Market information refers to those types of information that may be gathered from salesmen, customers, competitors and other sources. The information obtained under this heading may apply to either new products or existing products. It is this area that has been particularly weak in providing needed input to the planning process.

In new-product introduction the sequence of events is as follows. Fabric styles are designed in anticipation of upcoming "markets." Approximately three months before a market the salesmen take sample swatches of new fabrics to customers for showing. From among the many new styles and colors offered, a customer may wish to consider only a few in his fabric selection process. He therefore requests that the mill provide him with a sample[16] of the fabric for use in his selection process. Having received samples from both Sewanee and his other suppliers, the furniture manufacturer goes through his fabric selection process. If he decides to introduce a Sewanee fabric at the upcoming market he will order small yardages to use in upholstering of furniture to be displayed at the market.

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[16] The mill produces sample swatches for distribution to customers. Records are kept of sample activity. Such records indicate the number of samples requested for various fabric styles and is reported on a monthly basis.

At the market show the furniture manufacturer receives orders from his dealers around the country for furniture covered in specific fabric styles and colors. This generates orders for fabric to the mill. The ability of the mill to respond to these initial "placements" is crucial. Getting a piece of furniture covered with upholstery and onto a dealer's showroom floor is the primary concern of the furniture manufacturer. This is the manner in which he generates sales or orders. It is also the way in which the fabric suppliers generate "repeat" sales of his fabrics. A fabric must be shown to the customer before he will order it. It is essential for both the furniture manufacturer and the fabric supplier to expeditiously get their goods out. Failure to do so results in lost sales and dealer dissatisfaction.

To this point several important events have occurred. First a number of furniture manufacturers have requested samples for use in their fabric selection process. And secondly, a number of those who considered various Sewanee fabrics decided to show them at the market.

The sample activity history is useful from two aspects. Our statistical analyses indicated close relationships between fabrics that experienced high sample activity and later showed excellent sales results. In addition, we learned that salesmen were able to predict with reasonable success those fabric styles that would be well-received at the market, based almost entirely on sample requests and customer comments received. However, the significance of sample activity is given additional weight if the customer has adopted the fabric for inclusion in his market show. Furthermore, if a large national company, such as Levitz Furniture, adopts a fabric it usually proves to be more significant than if a smaller and localized concern adopts the same fabric.

Knoweldge of such information makes the salesman a most valuable information source, one that has all too often been ignored. Salesmen have in the past generated feedback to the mill on the acceptance a fabric was experiencing prior to the market. In two instances the mill was advised that the particular fabric style would be an unqualified success and that volume orders should be anticipated. However, for a number of reasons the mill did not prepare adequately for the orders that were generated at the market. It was totally unable to meet the demand that ensued. Many dollars in lost sales and reduced credibility were the result. Such a situation is a disaster for salesmen, management and the customer. Everyone loses a little, but the mill suffers the greatest in loss of customer faith and, possibly, future orders.

The point to be made is simply that with regards to new product introduction the salesman is a bountiful source of information. How might such information be used in planning? Clearly the salesman can't be expected to predict accurately the acceptance of every new product. But he can provide information about which fabrics are most likely to prove successful with his customers. It is the task of management to gather this information from the salesmen in the regional sales offices and to make value judgements and decisions based on the aggregate perspective.

Such decisions might include: the ordering and stocking of yarns required in the production of certain new fabrics; setting a schedule to convert looms over to the production of these new fabrics; producing to stock for some new fabrics to enable rapid delivery of market placement orders; and providing for additional productive capacity to meet anticipated demand.

It should be clear from the above discussion that it is to the mutual benefit of Sewanee and its customers to establish a close working relationship. The furniture manufacturer needs the fabric from the mill in order to sell his product. The mill needs to have the furniture manufacturer's product on display to generate additional sales of his fabrics. This mutual dependence suggests that the second source from which field information might be drawn is the furniture manufacturer. We shall term this source customer information.

Customer information is of several types. Examples of the types of information that might prove useful to management in production planning are listed and then discussed below.

1. When does the furniture manufacturer make fabric additions and deletions (other than at the markets)?
2. Are such fabric deletions communicated to the mill in a formal manner, or are such procedures informal?
3. Why are fabrics being dropped from the furniture manufacturer's line?
4. How long does the furniture manufacturer normally retain a fabric in the product line once adopted?
5. What special requirements or conditions does the furniture manufacturer face?
6. What trends, if any, does the furniture manufacturer foresee or predict in his fabric selections for the future?
7. What problems, if any, is the furniture manufacturer having in obtaining fabrics from Sewanee as compared with other suppliers?

Furniture manufacturers differ in the breadth of fabric line they carry. Style-conscious firms may have as many as 600-700 different style/color combinations to offer. Large firms engaged in production line making of furniture may carry only 200-300 style/color combinations. Each firm, however, periodically deletes items from its offering. Some perform this task in a very informal manner; others accomplish the task in a systematic fashion, usually in conjunction with the market selection process. Most furniture manufacturers, however, do not communicate their fabric deletion decisions in other than a most informal manner, usually through a sales representative. Often the information never reaches the mill. However, such information can be useful to Sewanee's planning effort.

Periodically, Sewanee must make its own product deletion decisions. Knowledge of how such decisions will affect its customers is certainly pertinent. In addition it is valuable to have a feel for why manufacturers are deleting certain fabrics. Is quality a problem or has the style simply failed to generate sales? It may be that delivery has been particularly poor or a competitor supplier is offering the same fabric at a lower price. All of these issues are valid concerns for Sewanee. The mill must obtain feedback from its customers, and asking the question "why" should aid this effort.

Another consideration entering Sewanee's product deletion decisions is the length of time the style has been in the line, for dropping an item too soon is likely to cause havoc with customers. Most furniture manufacturers will give a fabric style anywhere from eighteen months to several years in which to prove itself. However, if after one to two years an item has not established itself there is reason for doing away with it. Every manufacturer is somewhat different with respect to this issue, but in general

the industry expects a mill to maintain a fabric for at least two to three years. For Sewanee this often means keeping items in the product line that might not be in the best interests of the mill, but it is necessary to maintain customer goodwill.

Furniture manufacturers have been described as characteristically different from one another. Each has his own pecularities and special needs. Because of these anomalies Sewanee needs to be attentive to those requirements of customers that might ordinarily be overlooked. This is particularly true for "special" accounts - those manufacturers who account for large percentages of sales. However, it is just as easy to hurt a small concern, for failure to meet scheduled deliveries to such a manufacturer can severely impair his production operations. Furthermore, through its "visible" interest in a customer, Sewanee is able to communicate its dedication to providing the best possible service.

Because the furniture industry is the amalgam it is, trends in fashion and style can be short or long-lived. The furniture manufacturer is perhaps the best source available for discerning these trends. To remain a leader in the textile upholstery industry Sewanee must continuously monitor its customers for information on trends in the industry.

Finally Sewanee must prod its customers for feedback on how it is performing vis-a-vis its competitors. What areas could show improvement? A sincere effort must be made to convince the customer that the mill _is_ concerned about it performance and wants to hear suggestions for improvement.

We introduced this section by stating that there are sources of information that need to be tapped. We have seen that the salesmen and customers are two such sources of input to the planning process. There

are others, but the two presented are the most important. It is our contention that a systematic means needs to be adopted for capturing such information. Assessment of this information is properly accomplished in the resolution process to be discussed later.

4.3.3 Historical Data Inputs

The contribution of historical data as an input to production planning at the current time is not significant. Chapter 3 has presented a rough analysis of three major areas of interest in the available historical data, and it is the task of this section to link this information with the aggregate planning process.

The three types of data to be discussed are sales data, market analysis of customer buying patterns, and sample distribution data. The contribution of each will be discussed in turn.

The benefits to be derived from using historical sales data for predictive purposes are somewhat reduced in a style goods firm such as Sewanee. The reason is, of course, that the product life cycle is generally short for large volume fabrics. There is, however, potential for using forecasting techniques for products after their introduction. This point was illustrated by the sales plots in Chapter 3. Furthermore, Sewanee's management has available to it historical data for the entire product life cycle of many fabrics. The use of product life cycle information could be very valuable, if used appropriately, in the process of planning for expected production levels. For example, a product on the downward sloping side of its life cycle curve would be allocated productive capacity at a decreasing rate when the aggregate production plan is established.

The potential also exists for forecasting product demand at the group level. Again the graphical representation of sales data for the print and polypropelene lines indicated a near-linear relationship over a two-year period. With a knowledge of expected demand for major product lines at its disposal, production management has information upon which it can base capacity allocations for intermediate yarn preparation processes. And, in the case where loom modifications are required to weave a particular line of fabrics, capacity alterations decisions can be made.

Despite the fact that Sewanee's production management does not presently use historical data to any appreciable extent, the information for many useful planning inputs exist within the firm's current systems. Systematic collection of this information and analysis could potentially aid the planning process significantly. Specific recommendations might include separate analysis by product group of sales data, analysis of sales data for major fabric styles, and monitoring of the product life cycle for major fabric styles. The process of monitoring these variables should be continuous with management considering their usefulness as part of the ongoing planning process.

The analysis of Sewanee's market data in Chapter 3 supported a number of preconceived suppositions about their product line, not the least of which was validation of the extremely rapid growth in both end products and components. In addition, the analysis of the top-ten accounts sales history for 1973 clearly demonstrated that 30% of the fabric styles sold to these customers comprised 90% of the volume purchased by this group. The fact that there was very little overlap in purchases further emphasizes the extreme breadth of Sewanee's product line.

It is evident after examining customer analysis data that Sewanee can use a similar approach to monitor the breadth of their product line and answer questions, in terms of sales volume, as to what the effect of selected fabric style deletions might be. Input into the aggregate planning process, this information thus provides both a planning and a control function.

The third major area of interest in the historical data analysis is sample fabric information. Clearly, the value of a leading indicator, such as sample activity,would be significant in a style goods industry. This is especially true for projecting potential sales based on sample activity. The considerations mentioned in Chapter 3 withstanding, there does appear to be some correlation between existing sample data and ultimate sales volume for the test group. While there remains a significant amount of research to be done in this particular area, improvements in the collection of sample distribution data should serve to make it a more meaningful input to the planning process. In sum, the contribution to be expected from sample activity analysis remains a potentially valuable input.

What remains here is for the information discussed in the preceeding paragraphs to be linked to the aggregate planning process in a formal manner. The primary intent in the analysis of sales, market, and sample data was to demonstrate to Sewanee's management the information that can be gained from similar approaches. The actual use of this information ranges from subjective in nature, considering product life cycle curves, to highly quantifiable forecasts of sales. The information is intended to support management decisions captured in the resolution process and be reflected

in the master schedule. Over and above this relationship much of the information is valuable input for the capacity planning process.

In summary it appears that Sewanee has available several sources of historical data that should be collected and utilized in the production planning process. Future development of these informations sources will require added sophistication in the analysis process, and considerable effort in further detailing and collecting support information.

4.3.4 Management Input and Research and Development

As is usually the case, management carries into a decision process subjective bits of information that may be described as both intangible and non-quantifiable. We present this source of information as an input to the aggregate production planning process in recognition of the fact that it is often the most important one. It reflects management's "hunches," "gut feelings," and the like. It is difficult to be precise about the nature of such information, because it's content is usually unknown and therefore defies measurement. It may, however, be noted that this source is a "dynamic" one in the sense that the information brought to bear in the planning process may reflect market forces that have just been recognized. In short, it allows management to inject intelligence into the process which may not have previously been captured.

One source of information relevant to the production planning process, but presented as an explicit consideration to be injected by management, is research and development (R&D) efforts. Research and development has traditionally been allowed to set its own direction. However recent problems reflecting lack of effective coordination between R&D and production

personnel dictate that a closer liason be established. The aggregate production planning process is the proper forum for effecting such communication.

Top management should ultimately establish limits on the scope of new product (fabric) development. Typically this has not been done sufficiently well, and a proliferation of new product introductions for each market has resulted. With the end product expansion the mill has experienced an even greater yarn component explosion. It is not at all uncommon to find R&D adding new yarn types in fabric development when existing yarn types could achieve the same result. Lack of effective control over yarn types used in R&D has resulted in inventories of some yarns that are rarely, if ever, used. It is essential that management effectively constrain R&D efforts by dictating that "standard"yarn types be used in product development, with new yarn type additions closely controlled. In addition, it would be equally advantageous to systematically phase out inventories of yarns that are no longer active.

The impact of research and development efforts is further appreciated when we consider that R&D can act to "balance" the product line with respect to yarn production capacity. If R&D develops a line of fabrics that heavily utilizes one group of yarn types, it is possible that introduction of this line will place an undue burden on one segment of productive yarn capacity. A prime example of this was the Eastman line. At the same time another area of yarn production may be forced to shut down due to lack of demand for such yarns. Management must first insure that R&D develops fabrics with these consideration in mind, and then bring knowledge of R&D efforts to the production planning process.

It should be clear that top level management must make strategic decisions in the aggregate production planning process. A stratetic decision to develop a particular product line, such as the Eastman group, may require significant capital expenditures to provide the capacity required to meet expected demand. This will clearly impact the overall production planning effort. Similarly a decision to drop a commercial fabric line may render a large yarn inventory obsolete. These considerations must be evaluated. Management's participation and perspective is essential to effective production planning.

4.4 The Aggregate Production Planning Process

The aggregate production planning process has been designed to capture the inputs from the market, resolve them into useable production requirements, identify a capacity plan for the firm, and provide the input for requirements planning. The mechanics of this process will be the topic of this section. Specific coverage of the resolution process, the "master schedule," and allocation of capacity by major product groups and subsequently to major product lines will be presented.

4.4.1 The Resolution Process and Master Scheduling

It is the specific function of the resolution process to extract from the available information the relevant items and propose a level of production activity that the firm can expect in future periods. As the system is designed, the resolution process is a management task.

The internal workings of the resolution process entail very subjective consideration of the available information. On the basis of the available

input, management answers the question "What should we plan to produce in the following time periods?" Specific consideration of the confirmed orders, coupled with a decrease or increase in individual product areas provides the basis for determining the actual production requirements. The final decision in this area is envisioned as a report, the master schedule, that outlines for each time period management's judgement of what expected production requirements will be. The level of product aggregation most appropriate for this determination is the fabric (style/color) level. It is important to note that this procedure is not advocating that any fabric currently active in the firm's records is to be reviewed, but simply that those fabrics which make substantial contributions to sales should be closely monitored. Other fabrics with outstanding orders will follow the natural flow of the system through the bill of materials processor and on to scheduling and weaving.

If an item is expected to experience lower or higher sales, or require finished goods inventories the mechanism for introducing these changes into the system is the master schedule. Clearly, the master schedule is the summary of management's expectations from the market over a finite time horizon, and it is also one of two major links between the market and the production scheduling system. Development of the second link between planning and production, the capacity plan, follows.

4.4.2 Capacity Planning

The process labeled "allocation of production capacity to major product groups" involves the active participation of production management in the decision of "how many looms should be allocated to a major product group."

Inputs to this decision process are the master schedule and the current loom configuration. The decision made at this level is not one of explicitly allocating particular fabrics to looms but rather the aggregate determination of how many looms should be dedicated to Eastman production, poly production, etc. One important feature is the ability to change loom configurations, thus altering available capacity, or addition of looms thus adding additional capacity. Changes in either way results in a change in the loom capacity plan. It is by this mechanism that production management can shift their capacity to meet changes in demand or decisions by the firm to allocate its productive capacity in other areas for reasons which might include profitability of particular product groups.

Following the decision on the allocation of capacity to major product groups, this same decision must be made with respect to subdivisions within the groups. Of major concern are the major product lines[17] within product groups. In effect, this is a more detailed plan of how capacity is to be allocated.

It has not been stressed in the preceeding paragraphs, but the capacity plan like the master schedule is not a static, single point in time decision. The capacity plan should be updated weekly along with the master schedule and developed over a time horizon judged appropriate by management.

A couple of issues with respect to capacity remain unresolved at this point in time. First, the details of work center loading have been omitted intentionally. The focus has instead been on aggregate planning because this is the area of greatest concern when extracting relevant information from the market and linking it to the production process. A

[17] A line is composed of fabrics with similar construction without regard to color.

second area of capacity that has been neglected is the planning of capacity for "downstream" activities which include yarn and beam manufacturing. Capacity limitations in these areas are realized by the proposed system when yarn and warp requirements are butted against inventories, both actual and planned, for each period in the planning horizon. If the system was to be presented in more detail, outlining the process for allocation of capacity for yarn preparation and beaming would be of concern.

The feedback loop from the requirements planning process in Figure 17, labeled reschedule, is designed to allow rescheduling of the system throughput if capacity limitations or inventories are exceeded. The manner in which rescheduling occurs is modification of the "master schedule." The system then follows the normal flow through loom capacity planning and the bill of material explosion.

It is obvious that the discussion to this point has said little about the planning of facilities for intermediate processes, and control has been emphasized relatively more strongly. The point in presenting the model in this form is to assure that the model is robust enough to serve as a framework within which detailed procedures can be developed for intermediate processes, yet the present discussion must maintain a clear view of the more aggregate problem of planning aggregate production on the basis of market requirements.

A final consideration in the discussion of the capacity plan involves the specification of actually how capacity should be measured at Sewanee. Two possible measures are "pieces" and "picks." The variability in piece output rates between fabric types somewhat restricts the use of this measure. The picks measure is a generally accepted measure which provides a basic measure of throughput that is independent of the fabric construction.

Currently Sewanee specifies fabric co ructions in terms of picks per inch and maintains records of loom pick counts over time.

The actual process of incorporating the standard pick/inch concept would require addition of standards in picks/inch to be added to fabric records, and generation of pick capacity by loom throughout the mill. This appears to be the most basic unit of comparability among fabric production times, and probably the easiest control to implement.

4.4.3 The Detailed Scheduling Process

The aggregate production planning process has been discussed at length and the linkage issues with both the inputs and outputs to the planning module finalized. Following the linkage paths from capacity planning and the bill of materials explosion will greatly enhance an understanding of how an actual fabric is scheduled for production.

The bill of materials explosion is a component by component explosion of the requirements generated by the "master schedule." These requirements, separable into warp and fill yarns, generate demand for specific fabric components. In a typical materials requirements planning system order issuance for production or purchasing would take place after the requirements that have been generated are netted against actual and planned inventories over the planning horizon. Should the present capacity at this stage be unable to meet the requirements the feedback loop to the master schedule will allow capacity bottlenecks to be alleviated.

If the requirements are available for production of fabric orders for the planning period the process of warp scheduling proceeds. The assignment of warps to looms is again responsive to the capacity plan that has been generated.

The economics of fabric production make scheduling warps a viable alternative to direct assignment of particular fabric constructions to looms. Significant costs are incurred in warp changeovers, and hence it is desirable to minimize these costs in lieu of the relatively less severe cost penalties associated with changing fill yarns.

The actual scheduling process of warps to individual looms must of necessity evaluate a number of tradeoffs. Due date, present loom setups, fabric market request, and future demand for the warp in successive time periods comprise major considerations.

At the fabric scheduling level the detail of assigning particular orders for fabrics must be converted into a working schedule. Again consideration of fabrics for market introduction, fabrics with future demand, and due dates are major considerations.

The emphasis in the preceeding discussion has been one of demonstrating how Sewanee can tie its production process to the available market information in an effort to better utilize its productive resources. The highly variable demand experienced in the fabric industry and the short product life cycle make planning difficult but potentially a very rewarding process. Key to the successful use of any planning model, of course, is a practical implementation procedure. In the operational procedures the critical links between input information and the planning module must be clearly defined and timed to the needs of management. The aggregate planning function itself, either succeeds or fails based on the quality of information management has available and the effectiveness with which this information is used. Critical are such factors as the manner in which the master schedule is produced and the design and implementation of capacity

planning programs. Once the planning process is completed, it must be effectively linked to the operational issues such as requirements planning and warp scheduling. And finally, there must be provision in the system for identifying bottlenecks and rebalancing the system to achieve the desired throughput.

The following chapter will discuss a few of the implementation issues anticipated with Sewanee's transition to integrated production planning and control.

CHAPTER 5.

KEY ISSUES IN THE IMPLEMENTATION PROCESS

The preceeding chapters have served to present the production system as it currently exists at Sewanee, and a normative model of a proposed system to remedy crucial problems. In this chapter we will reiterate the key issues that have been noted in the text and discuss to a limited extent what can be expected from the implementation process. An attempt will be made to extract and examine the major issues, rather than categorizing them within elements of the planning framework.

The major issues to be discussed include the information usage, capacity planning, and master scheduling. And finally, comments on the implementation process.

5.1 Historical Data Utilization

It is clear after discussing in Chapters 3 and 4 that the use of historical data and market information is vital input to the planning process. There exists a relatively wide gap between the type of ongoing system proposed and the present system at Sewanee. Although much of the information is available, little of it is used explicitly in the form prescribed in Chapter 4.

To improve the current use of information at Sewanee will require a definite commitment on the part of their production manager. Not only will technical details concerning information collection and analysis have to be worked out, but communication of information in a more formal manner is required. The aggregate planning process depends heavily on the advances made in more effective use of the available information.

5.2 Capacity Planning

The normative approach to aggregate production planning in Chapter 4 covered a far broader concept of planning than is currently embodied in Sewanee's operations. Some of the issues raised are not considered by Sewanee in making decisions related to capacity allocations to product groups; others exist and are used, but there is no linkage between the elements of the planning process and operational activities such as production scheduling.

From an aggregate point of view, the subject of capacity planning is critical to the success of the proposed integrated production planning and control system. The concept of utilizing available information to formulate a production strategy and guide the allocation of productive resources within the constraints of a capacity plan is an issue that requires immediate attention by Sewanee's production management. Furthermore, once defined, the plan must be translated into operational procedures and controls.

A primary prerequisite for operationalism of the capacity plan is, of course, the establishment of adequate capacity measures. The use of "picks" has been advocated by Sewanee's management and appears to be a viable alternative. Broader, less exact, measures under consideration would include piece production rates. There is however significant variability inherent in using pieces as a measure. Primarily, piece rates vary with the type of fabric being produced, and secondly the piece rate observed during a time period may not actually reflect the loom capacity because of inefficiencies in areas such as materials flow or scheduling.

It remains for the production management team at Sewanee to devise their own time table for the planning process. In addition, the link between capacity planning and budgeting will merit considerable effort.

Although this particular subject was stressed only lightly in the literature survey, the long term success of Sewanee's production management will require planning of capacity and expenditures based on the assessment of trends in the fabric market. In order to accomplish this objective they will most certainly need to consider longer-term planning and resource allocation procedures than were discussed in the body of this thesis. Furthermore, the link between longer-term planning and aggregate production planning, must be clearly defined and made operational.

5.3 Scheduling

The issue commonly referred to as scheduling at Sewanee was formally described in Chapter 3. In the model of Chapter 4 scheduling was separated into master scheduling, detailing of end product requirements time phased over the planning horizon, and detailed scheduling, or loom loading.

The scheduling of end product requirements in the master schedule is a large step for the production control staff of Sewanee. Their present approach to scheduling takes a very short-term look at the requirements. The master scheduling approach allows management to view their requirements for the entire planning horizon. Coupled with the subsequent explosion of requirements and netting of requirements against inventories, potential problems in future production scheduling can be corrected and a smooth operational plan developed.

We feel that the concept of the master schedule brings to the production management system a vital feature that has been missing at Sewanee. Rather than sequential decisions on the allocation of production requirements, management will be looking at the impact of the set of requirements on their resources over the planning horizon. The ability to view the

process in this manner should allow for better decision-making on the part of production management.

The detailed scheduling process at Sewanee also suffers from the very narrow short-term, day-to-day approach. Further restraints are included when the assignment of warps to looms is accomplished in sequential order. There are at any one time a large number of warps competing for assignment to looms. Unfortunately, the scheduling process to date has done little to consider the appropriate mix of warp assignments given the current demand requirements and production management's objectives. In keeping with the proposed production planning system for Sewanee, the allocation of particular warps to looms would be based on a priority system which would require a number of tradeoffs for each candidate in the warp backlog summary. This approach should yield improved performance over the present sequential method.

5.4 Comments on the Implementation Process

The conceptual framework provided in this study for an integrated production planning and control system provides a plan upon which detailed design work can begin. The modification of existing information sources and the introduction of new sources will have to be formalized into working reports designed to monitor the firms market and production activities. Having layed the conceptual framework, considerable design of the scheduling process and the automation of this task, both at the master schedule and detailed scheduling level, must be accomplished. The existing bill of materials for fabric constructions that is currently being used can be extended to interface with the master scheduling process to develop the time phased requirements plan. Formalizing the priority assignment scheme

for scheduling individual warps to looms, and subsequently fabrics to warps, must then be accomplished.

Because of the magnitude of the physical data handling requirements the majority of the scheduling process will require electronic data processing support. It should be emphasized however that the master scheduling process requires the application of production management's subjective input to modify the data recorded in the processing system.

The last, and potentially the point with the shortest payback in terms of recognizable results, is the use of the available market and historical information as inputs into the production planning process. It is evident from the brief examination of Sewanee's information sources in this thesis that there is a wealth of potential available if the information the firm currently collects is used effectively. Structuring this information is the key to the success of all the downstream activities.

CHAPTER 6.

CONCLUSIONS AND RECOMMENDATIONS

The major premise of this thesis has been that scheduling of production activities can be enhanced by the use of available information in a formalized aggregate production planning procedure. We have observed that several sources of information exist which serve to fulfill this function. The following paragraphs briefly summarize these observations.

The first of these information sources is historical sales data. From this data we were able to discern life cycle curves for various products. In addition, we noted that a small group of both customers and fabrics were responsible for a large percentage of fabric sales. The implication is that close attention should be given these customers and fabrics. Effort should be devoted to those areas where the payback is greatest.

Product "sample" data analyses indicated a close correlation between "sample activity" and resulting sales. This correlation suggests that greater attention should be directed to collection and evaluation of sample information. The potential benefit of information in this area as a planning aid for capacity allocations is immense.

Market information, from both salesmen and the customers themselves, is another valuable source of input to the planning process. Salesmen were found to be well aware of the trends and potential of various fabric introductions. Their knowledge, combined with sample data collected at the mill, could serve as a most powerful planning aid for management.

It was found that an essential ingredient for success is a thorough understanding of the customer and his problems. In a highly competitive

style conscious industry it is most important to have a clear awareness of the customer's characteristics and needs.

A close liason between research and development and production planning is seen to be crucial to mill operation. Management must insure communication is effective and that research and development projects complement the needs of production with respect to capacity requirements and materials requirements.

The formalized aggregate production planning system proposed is the key element. It ensures the systematic and explicit consideration of the several information sources. Additionally, it provides a means of reducing the available information to a form that is compatable with operating at all levels. Adoption of a formalized process helps to ensure that management will continually evaluate where the firm is headed, what the market trends are, what the customers needs are, and finally allow production management to plan, based on this information, a schedule to meet the requirements.

The planning process must be dynamic and responsive to the changing environment in which Sevance operates and as such it must provide for the capture of information that will monitor the key variables in the environment for management. Personnel may change, but the planning process must be capable of supporting management's decision needs in an ongoing manner.

In support of the conclusions reached, there are a number of recommendations for future work that merit consideration. It is appropriate to amplify these suggestions in the following paragraphs.

Areas in which further work along these lines might be conducted include the development of a predictive model for fabric sales. Such a model might include as variables such things as sample activity, salesmen

reactions, past sales of similarly constructed fabrics, and perhaps some subjective management measure of acceptability.

In addition much downstream work in the integrated production planning and control system needs to be accomplished. The links between the master scheduling process and the detailed scheduling process need to be further refined and perhaps automated. The clearest candidate for automation is the assignment of specific customer orders to production on specific looms on a given day. In fact this task is currently in the evaluation stage and may soon be automated. A very real concern here should be to look at the system end product that is envisioned at some time in the future. Care should be taken not to design a detailed scheduling system that might later be incompatible with the production planning effort. For this reason we suggest that management insures the broad specs for the overall system be agreed upon before automation of any one part is undertaken.

Another potentially profitable area of research is related to pricing strategies for upholstery fabrics. Very little work has been done in this area. In fact management at Sewanee is very much in the dark as to profit margins on its various fabric lines. Such a determination of appropriate pricing strategies and profit margins could well have strategic implications. Decisions to enter or get out of a product line could well rest on the knowledge supplied by such information.

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